SPD-717-01

PROPULSION EXPERIMENTS WITH A DEEP TUNNEL PLANING HULL

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

PROPULSION EXPERIMENTS WITH A DEEP TUNNEL PLANING HULL

by

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and

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SHIP PERFORMANCE DEPARTMENT

February 1977

SPD-717-01

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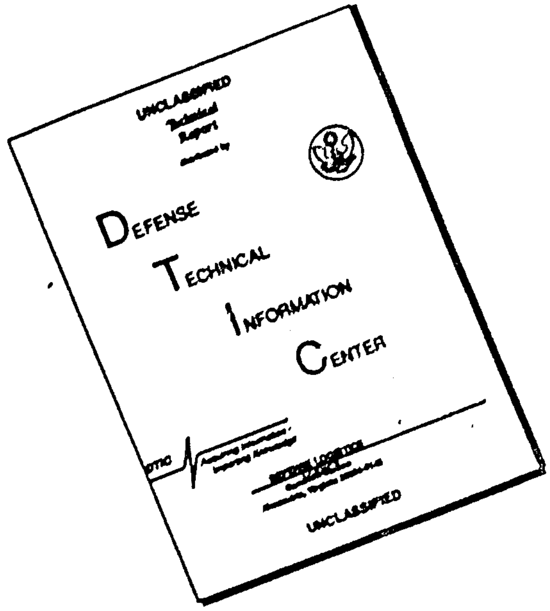

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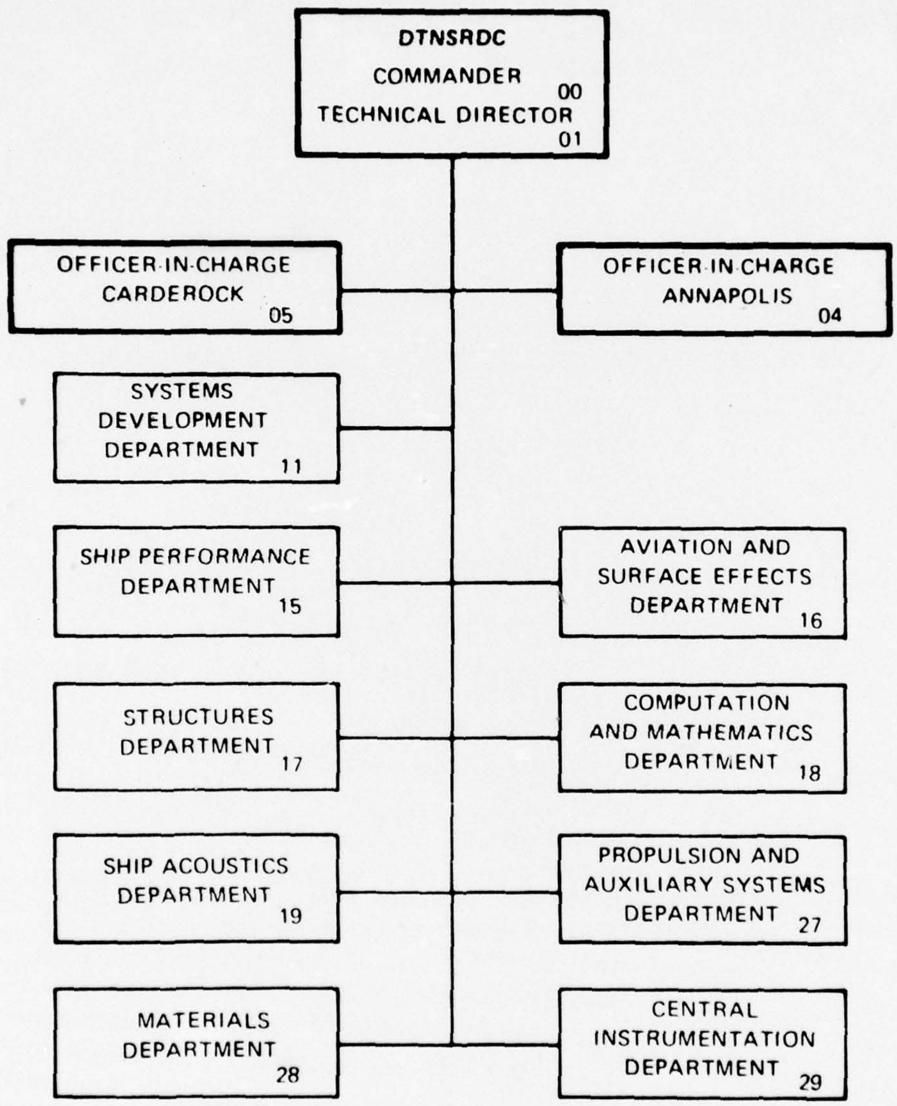

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: SPD-717-01 (14)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Propulsion Experiments with a Deep Tunnel Planing Hull (6)		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Walter E. Ellis, Reuel Alder (10)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: David W. Taylor Naval Ship R & D Center, Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Element 6.3586N, Unit 1-1140-606
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Sea Systems Command (SEA 03221), Washington, D.C. 20350		12. REPORT DATE: (11) Feb[redacted]77
		13. NUMBER OF PAGES: 57
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 67p.		15. SECURITY CLASS. (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Tunnel Hull, Planing Boats, Shallow draft

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Resistance and self-propulsion data are presented for Model 5048 fitted with tunnels equal in depth to basic propeller diameter. The relative merits of seven combinations of LCG position, propeller diameter and trim tabs are discussed. A forward LCG position offers the best combination of draft and shaft power. Comparisons are also made with the same hull without tunnels and with two sets of shallow tunnels. The 100 percent tunnel is inferior to both shallower tunnels in draft and power requirements, but it gives superior propeller

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S/N 0102-014-6601

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20. (Cont.)

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protection for beaching operations. The 65% tunnel requires the least draft and gives good propeller protection, but it requires more power than the 40% tunnel.

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NOTATION

A_P	**Projected area of planing surface, exluding area of external spray strips**
B_{P_X}	Maximum breadth over chines, exluding external spray strips
D	Propeller diameter
F_{n_∇}	Volume Froude number $V/\sqrt{g\nabla^{1/3}}$
g	Acceleration of gravity
J	Advance coefficient, V/nD
K_Q	Torque coefficient
K_T	Thrust coefficient
LCG	Longitudinal center of gravity
LOA	Overall length
L_P	Projected length of chine
n	Propeller rotational speed
P.C.	Propulsive coefficeint, $\eta_H x \eta_R x \eta_o$
P_S	Shaft Power
R_T	Total resistance
$R_{T_{AX}}$	Appendaged hull resistance: X = P for parent hull X = T for tunnel hull
$R_{T_{BX}}$	Bare hull resistance: X = P for parent hull X = T for tunnel hull
$R_{T/\Delta}$	Resistance coefficient
SHP	Shaft horsepower
t	Thrust deduction fraction $1-(R_T/T)$
T	Thrust
V	Speed

w_Q	Taylor wake fraction determined from torque identity
w_T	Taylor wake fraction determined from thrust identity
∇	Displacement volume
Δ	Displacement weight
$\eta_A (= \frac{R_{T_{BP}}}{R_T})$	Ratio of bare parent hull resistance to resistance with appendages of hull being considered
$\eta_B (= \frac{R_{T_{BX}}}{R_{T_{AX}}})$	Ratio of bare to appendaged hull resistance for the same hull configuration
$\eta_C (= \frac{R_{T_{BP}}}{R_{T_{BX}}})$	Ratio of bare parent hull resistance to resistance of bare hull in question
$\eta_D (= \frac{R_{T_{AP}}}{R_{T_{AX}}})$	Ratio of appendaged parent hull resistance to resistance of appendaged hull in question
η_H	Hull efficiency $(1-t)/(1-w_T)$
η_o	Open water propeller efficiency
η_R	Relative rotative efficiency

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ABSTRACT

Resistance and self-propulsion data are presented for Model 5048 fitted with tunnels equal in depth to basic propeller diameter. The relative merits of seven combinations of LCG position, propeller diameter and trim tabs are discussed. A forward LCG position offers the best combination of draft and shaft power. Comparisons are also made with the same hull without tunnels and with two sets of shallow tunnels. The 100 percent tunnel is inferior to both shallower tunnels in draft and power requirements, but it gives superior propeller protection for beaching operations. The 65% tunnel requires the least draft and gives good propeller protection, but it requires more power than the 40% tunnel.

ADMINISTRATIVE INFORMATION

This report was authorized and funded by the Naval Inshore Warfare Craft Office (Code 114) of the Systems Development Department, David W. Taylor Naval Ship R&D Center, which provides Technical Management for the Naval Inshore Warfare Craft Program, SSW-02 (previously the Special Warfare Craft Program, S38-20X). The Principal Development Activity is the Naval Sea Systems Command with program management in the Advanced Technology Systems Division (SEA 03221). Program funding is under element 6.3586 N. This specific task was funded under center work unit 1-1140-606.

UNITS

U.S. customary units were used for the original measurements and calculations. SI (Metric) equivalents of US units are given where they first occur in the text and elsewhere if required for clarity. U.S. units are used alone when their SI equivalents have previously been given and where the unit performs an adjectival function, as in "6 inch propeller". This usage has been adopted to facilitate cross-referencing between this and previous reports in the tunnel-hull series.

The appended data tables, prepared before the adoption of SI units, have not been revised to incorporate SI equivalents due to time and cost constraints.

INTRODUCTION

Minimum navigational draft is a prime requirement for small high performance craft intended for use in shallow water. Conventional designs have propellers and appendages which project below the baseline, and the usual approach in reducing draft is to reduce propeller diameter or adopt waterjet propulsion, techniques which are not necessarily beneficial in terms of propulsive efficiency.

An alternative approach is to house the propellers and appendages in so-called tunnels, or troughs in the hull bottom. By thus raising the propellers relative to the baseline, the draft can be reduced while retaining the same propeller diameter. Propeller efficiency may even be beneficially affected by the partial shrouding effect of the tunnel wall. On the other hand, the loss of planing surface and changes in pressure distribution on the bottom may adversely affect the running trim, draft and resistance.

The general characteristics of shallow tunnel hull craft were explored by Harbaugh and Blount[1] in an experiment in which Naval Ship Research and Development Center Model 5048 was equipped with two sets of tunnels, accommodated within the original hull lines. Propellers of 6.00 inch (0.152 metre) and 5.25 inch (0.133 metre) diameter were employed. The tunnels were 6.062 inches (0.1540 metres) wide and had depths of 40 and 65 percent of the larger propeller diameter. Resistance and self-propulsion runs were conducted at Langley Field, Virginia.

The current experiment was more specifically intended to examine the potential of deeper tunnels as a means of providing increased propeller protection, especially for beaching operations. For this application overall efficiency is a secondary consideration and waterjets are often employed because of their comparative immunity to damage. It was hoped in this experiment to obtain similar immunity for propellers in deep tunnels while retaining the efficiency advantage of propellers over waterjets.

David W. Taylor Naval Ship R&D Center Model 5048 was fitted with a set of 100 percent deep tunnels and resistance and self-propulsion runs were conducted at Langley Field, for similar conditions of displacement and static trim to the earlier tests. Two other static trim conditions were also investigated, and in addition trim tabs set to 5° and 10° were fitted to the stern for an abbreviated series of runs. The same two sets of propellers used previously were again employed.

This report is in two parts. The first presents the results of the 100 percent tunnel hull experiments while the second compares the results of the current work with the previous parent and tunnel hull test results. Because a large number of hull configurations are discussed, particular care should be taken to distinguish between them. In this report, "parent hull" refers to the original model 5048 without tunnels. Tunnel hull forms are identified by the depth of the tunnels (40,65 or 100%). The 100 percent tunnel hull is further described in accordance with its LCG and trim tab configuration as outlined in Appendix 1. Any of these hull forms is also described as "bare" or "appendaged" depending on whether the normal appendages (rudder, propeller shafts and struts) were present. Finally, most of the tunnel hull configurations were tested with two sets of propellers.

MODEL DESCRIPTION AND EXPERIMENTAL PROCEDURES

Model 5048 had been selected by Harbaugh and Blount as the parent hull from hydrodynamic and design considerations. The model specifications are given in Table 1. The model was modified to accept two fiberglass tunnels, details of which are shown in Figure 1. The upper curved boundaries were formed by sections of two 6.062 inch (0.1540 metre) diameter cylinders intersecting at 12 degrees, and the side walls were flat vertical sections parallel to the center line. Appendages comprised twin rudders (mounted in the tunnels), propeller shafts and struts.

TABLE 1 - Specifications for Model 5048

LOA	10.125 ft	3.084 m
L_P	9.75 ft	2.972 m
B_{PX}	2.62 ft	0.798 m
A_P	20.65 ft^2	1.918 m^2
Projected area per rudder	0.078 ft^2	0.00725 m^2
Deadrise (afterbody constant)	8.5 degrees	
Shaft angles (with respect to baseline, for 100% tunnels)	1.17 degrees	

Trim tabs were fitted to the transom for some runs, and details of their location and dimensions are given in Figure 2. Stern views of the hull with 6.00 inch diameter propellers, appendages and trim tabs in place are given in Figure 3.

The propellers were left- and right-handed pairs, having diameters of 6.00 and 5.25 inches (0.152 and 0.133 metres) and nominal tip clearances of 0% and 7.1% of their diameters. Mean values of the open water characteristics of each pair of propellers are given in Figure 4.

The model was ballasted to a displacement of 340.5 lb (154.6 kg) for all runs. It was towed in the thrust line and for propulsion tests it was powered as closely as possible to the self-propulsion point. Five different configurations were tested as described in Appendix 1. Configuration 1 (LCG=39.8% L_p forward of the transom) corresponds to the configuration employed in previous experiments.

EXPERIMENTAL RESULTS FOR 100 PERCENT TUNNEL HULL

The hull characteristics for the five configurations tested are presented in Figures 5 through 9. The data have been non-dimensionalized (except for trim angle) for ease of comparison with previous tests, which were conducted at a slightly higher displacement (345 lb, 157 kg). The draft figures refer to draft of the baseline at station 10. Resistance values have been corrected to fresh water at 59°F (15°C), and only the horizontal component of towing force is reported.

Figure 10 presents the appendage drag factor η_B for configurations 1, 2 and 3. Care should be taken to distinguish between η_B (the ratio of bare to appendaged hull resistance for the same hull form) and η_A (the ratio of the resistance of the bare parent hull to the resistance of the appendaged tunnel or parent hull). Confusion can lead to serious misinterpretation of the data. Addendum 1 discusses this subject at length and should be referred to.

Propulsive characteristics ($1-W_T$, $1-W_Q$, $1-t$, and η_R) for configurations 1, 2, 3, 4, and 5 are shown in Figures 11 to 14. The computation of these coefficients was done using a computer program available at DTSNRDC which corrected the data to the self-propulsion point. Sample data from the earlier tests were also re-analyzed using this program and identical results to those reported earlier were obtained. The data were cross-faired using another standard DTNSRDC computer program to avoid anomalies arising from visual fairing of individual curves.

Data taken during the experiment are tabulated in Appendix 2. These data correspond to Langley water conditions, which are as given in the tables. Data which were obviously defective have been omitted, which accounts for missing run numbers.

Propulsive coefficients calculated from the Langley data (but not cross-faired) are presented in Appendix 3.

Trim, draft and propulsive coefficients for the basic condition with 6 inch propellers have not been plotted because their abnormal values and scatter indicate that the measurements are erroneous.

These measurements were the first to be taken during self-propulsion tests and problems with test techniques were encountered.

DISCUSSION OF 100 PERCENT TUNNEL HULL RESULTS

The general trends exhibited in trim, draft and resistance are consistent with the configuration changes represented in Figures 5 through 7. Rearward movement of the LCG results in increased running trim and reduction in the volume Froude number at which peak trim occurs. It also results in greater maximum draft, although the peak remains at $F_{n_\nabla} = 1.3$. A secondary hump occurs in the draft curves, roughly coincident with the point of maximum trim for each configuration. Both trim and draft are somewhat higher in the self-propelled condition than when towed. A contrast is evident in the comparisons of bare hull and appendaged hull behaviour, where the bare hull trim and draft are below, equal to or, above the appendaged hull values depending on the static trim. Despite this the appendaged resistance is always higher then the bare hull resistance.

A feature not noted in previous tests is the distinct trim and draft characteristics associated with each set of propellers. (Previously, one set of curves defined the trim and draft characteristics for both propeller diameters.) This may be due to the increased tunnel area acted on by the propeller flow field.

Comparing appendaged resistances, configuration 1, with the basic LCG position, has the lowest resistance up to $F_{n_\nabla} = 4.0$.

Configuration 2, with the LCG moved forward, shows higher resistance over the entire speed range. Configuration 3 shows higher resistance at intermediate speeds but matches configuration 1 from $F_{n_\nabla}=3.0$ to $F_{n_\nabla}=4.0$ and is slightly better at higher speeds.

A comparison of Figures 5, 8 and 9 shows that running trim is markedly reduced by the addition of 5° transom flaps. Changing to 10° flaps reduces the peak trim angle still further. Running draft is also reduced, but less dramatically, and at $F_{n_\nabla}=4.0$ it is practically unchanged for both flap settings. Resistance characteristics are practically unchanged up to $F_{n_\nabla}=2.5$, but above that speed the resistance increases sharply with increasing flap angle.

The appendage drag factor η_B (Figure 10) changes somewhat with LCG position, with configuration 1 giving the highest values, in the order of 0.97. The other configurations yield values in excess of 0.92 over the Froude number range from 2.0 to 4.0 (the accuracy of the calculation becomes questionable at lower Froude numbers because of the small numbers being ratioed). These high values probably reflect the shadowing effect produced by mounting the appendages in deep tunnels out of the free stream flow.

The propulsive characteristics are given in Figures 11 through 14. They exhibit many of the same features that were seen in earlier experiments. For example, η_R is higher for the propeller with zero tip clearance, (1-t) is relatively unaffected by propeller diameter, and $(1-W_Q)$ and $(1-W_T)$ are higher for the smaller diameter propellers. Reference (1) discusses these effects at length, so they will not be elaborated on here.

It should be noted that (1-t) is computed as the ratio of the horizontal component of appendaged resistance to the shaft line thrust, and this is consistent with the earlier tunnel hull data analysis.

Figures 15 and 16 are summary plots for each set of propellers, from which it can be seen that both sets of propellers are quite insensitive to changes in trim and draft arising from shifts in the LCG position, as evidenced by the similarity of the η_R, $(1-W_Q)$ and $(1-W_T)$ curves. The introduction of trim tabs produces greater changes in these coefficients, apparently because the low trim angles which are obtained serve to mask the propellers to greater degree.

PERFORMANCE EVALUATION OF TUNNEL HULL FORMS

The relative merits of the various tunnel hull forms tested during this program are discussed in the following sections. The main text presents comparisons of overall draft and required shaft power, the two most important performance criteria, so that the results of using different tunnels can be readily seen. This is an appropriate method of presentation because all of the models were derived from the same parent hull form.

An alternative method of data presentation is the one adopted in Reference 1. There the objective was to formulate a preliminary design method for obtaining initial powering estimates for tunnel hulls derived from any conventional planing hull form. In this method the bare hull resistance of the basic planing hull in question is used in conjunction with an efficiency factor $\frac{1}{\eta_A \eta_H \eta_R}$ (which accounts for all the interaction effects of the tunnels and propellers with the parent hull) to obtain an estimate of shaft power from

$$P_S = R_{T_{BP}} \quad V\left(\frac{1}{\eta_A \eta_H \eta_R}\right) \frac{1}{\eta_o}$$

Values of the efficiency factor were determined from the 40% and 65% tunnel experiments described previously.

Unfortunately, a data reduction error resulted in incorrect values of the efficiency factor being reported in Reference 1. This also led to misleading conclusions being drawn concerning the advantages of 65% tunnels, as a comparison of Reference 1 and this report will show. The opportunity has been taken in this report to correct these errors and to add data for 100% tunnels so that the usefulness of the design method can be extended. These corrections and supplementary data have been presented in the form of an addendum which can readily be copied and inserted in Reference 1.

Relative Merits of 100 Percent Tunnel Hull Configurations

Two measures of merit can be applied in attempting to evaluate the craft configurations reported. The first is obviously the navigational draft. The value reported here is the draft of the baseline at station 10 (transom), chosen because it represents the deepest point on the hull for the general case of bow-up running trim. Shaft power, obtained from the equation

$$P_S = R_{T_{BX}} \quad V\left(\frac{1}{\eta_B \eta_H \eta_R}\right) \frac{1}{\eta_o}$$

$$\text{or} \quad P_S = R_{T_{AX}} \quad V\left(\frac{1}{\eta_H \eta_R}\right) \frac{1}{\eta_o}$$

is the other measure of merit. As the equations make clear, shaft power depends on three separate factors, namely the bare or appendaged resistance of the hull in question, the interaction effects of the propeller and hull, and propeller open-water characteristics. The shaft power calculation in effect summarizes the results of variations in these factors which have already been illustrated individually. Therefore, in assessing the relative merits of the seven combinations of propeller diameters, LCG's and trim tabs under consideration, it is necessary to examine their power requirements to determine the net gains to be achieved by changing any of these parameters.

Power requirements and drafts of the seven configurations are summarized in Figures 17 and 18. Unfortunately, the parent configuration with zero-clearance propellers is not represented because of faulty data, so the comparison is incomplete; nevertheless the trends exhibited in these figures reveal that this configuration can be expected to have slightly lower draft then the same configuration with smaller propellers, and its shaft power input is likely to be about 7 percent lower, for $F_{n_\nabla} > 3.0$.

The figures show that the use of 10° trim tabs with zero-clearance propellers gives minimum draft at hump and up to $F_{n_\nabla} = 3.5$; however, this also requires the highest P_S expenditure at high speed. A better compromise is the use of 5° trim tabs, but the best appears to be the use of a forward LCG position, in which case the draft at hump increases only slightly (although it decreases less rapidly with increasing speed). The latter option requires significantly less power and avoids mechanical complexity and is thus the most desirable compromise.

Comparison With Previous Tunnel Hull Forms

The same two measures of merit which were employed in the foregoing section can again be used to evaluate the 100% tunnel hull relative to the parent and shallow tunnel hull forms. Figure 19 gives the shaft power requirements for the various hull-propeller combinations, all at LCG = 39.8%. The 100% tunnel - 6 inch propeller power requirements have been estimated from the trends observed during the current series of tests. It can be seen that the power requirements become progressively greater as tunnel depth is increased, to the extent that the 100% tunnel - 5.25 inch propeller combination requires 43% more power than the parent hull without tunnels, at $F_{n_\nabla} = 4.0$.

This increase in required power is due to two factors. First, there is a very marked increase in resistance associated with tunnels greater than 40% of propeller diameter. Figure 20 gives the percentage changes in resistance coefficient for various tunnels compared to the parent hull, both bare and appendaged. The 100% tunnel hull has as much as 50% higher resistance for the bare hull and 32% with appendages. This puts the deep tunnel at a serious disadvantage when computing the shaft power of the various hull forms. The increased resistance can only be offset by substantial increases in propulsive coefficient ($\eta_H x \eta_R x \eta_o$), and these unfortunately are not realized in practice (Figure 21). In fact, the opposite is true and this is the second cause of the power increase.

It could be argued that different propellers more suitably matched to the particular operating conditions would improve the relative power requirements of the deep tunnel hull, by achieving a higher η_o than the propellers actually used in the experiment. (This assumes that $\eta_H x \eta_R$ is not affected by changes in propeller pitch.) However, Figure 21 demonstrates that a sizeable increase in η_o is required simply to bring the propulsive coefficient back to its original value (i.e., the parent value) before beginning to compensate for the large increase in appendaged resistance. To fully compensate for both effects could require upwards of a 35% improvement in η_o, and this is unlikely to be achieved in practice. Further experiments with various propellers of the same diameter but with various expanded area ratios and pitches would help in clarifying this point. Meanwhile, it can be accepted that the penalty in shaft power is significant when 100%, and to a lesser degree 65%, tunnels are adapted.

The other merit factor to be considered is navigational draft. Here the comparisons are complicated because the propellers project below the baseline in some cases. Hence, overall draft becomes the criterion rather than draft of the baseline (although the two may coincide). Nevertheless, a comparison of baseline drafts serves as a useful starting point (Figure 22a). The values for the 100% tunnel hull are for the 5.25 inch propellers but the 6.0 inch propellers would give similar results. It is noteworthy that the baseline draft increases as tunnel depth increases. This is due to the loss of planing area and buoyancy aft and is accompanied by increased trim angles.

A different result is obtained when the overall draft, including propeller draft, is considered (Figure 22b). Here the parent hull clearly is at a disadvantage while the 65% tunnel hull, whose propellers do not project below the baseline, is superior. The 40% tunnels offer a fair advantage over the parent but the 100% tunnels are of minimal benefit. This is clearly due to the loss of buoyancy and planing area of the deep tunnels resulting in much deeper running draft visavis the shallower tunnels. (The estimated displacement of the various tunnels is: 40%, 12 lb; 65%, 17 lb; 100%, 34 lb).

In view of the small improvement in draft over the parent hull and the very large increase in shaft power required, it could be concluded that the 100% tunnel hull is inferior to shallower tunnel hull craft. However, this conclusion can not be considered absolute, for two reasons. First, all the hull-tunnel forms have been compared with LCG held constant and it has been shown, at least for the 100 percent tunnel, that other LCG positions lead to more favourable characteristics. Second, the objective in utilizing 100 percent tunnels was primarily to achieve increased propller protection. The alternative, the use of waterjet propulsion, would also involve a signficant performance penalty so that a more meaningful comparison would be waterjets versus deep tunnel propellers. In the absence of waterjet tests on the same hull, the comparison is not easily made but the propulsive coefficients greater than 0.6 which were recorded for the propellers in deep tunnels are not likely to be matched by waterjets. This is only a preliminary judgement, of course, and should be confirmed by waterjet tests in the same model.

For general operations the 40% and 65% tunnel hulls represent useful compromises of draft reduction versus required shaft power, with the choice depending on the relative importance attached to draft, propeller protection and power requirements. The 65% tunnel hull offers lower draft and greater propeller protection, at the expense of greater shaft power.

A factor to be borne in mind in considering the operation of planing craft in shallow water is the suction effect between the hull and the bottom. Investigation of this phenomenon[2] shows that sinkage and resistance can be greatly increased at near-hump speeds by decreasing the water depth, but at high speeds the resistance can be significantly reduced. These effects should be remembered when applying the data reported here to actual craft designs. The comparisons made here should, however, remain valid in determining the relative merits of the various hull forms.

CONCLUSIONS

The relative merits of seven combinations of propellers, LCG's and trim tabs have been determined using baseline draft and required shaft power as criteria, for the 100% tunnel hull. Zero-clearance propellers are slightly superior to smaller-diameter propellers. Trim tabs reduce the peak draft, which occurs at about $F_{n_\nabla}=1.3$, but require greater power at high speed. A forward LCG position gives almost the same peak draft without as great a power demand at higher speeds. An aft LCG position produces the best power characteristic but the greatest draft at hump.

The 100 percent tunnel hull has been compared with 40% and 65% tunnel hulls and with the parent hull without tunnels, using similar criteria. Power requirements become progressively greater as tunnel depth increases, and this is primarily due to increased hull resistance. The 100% tunnel requires about 40% more power than the parent hull at $F_{n_\nabla}=4.0$. Changes in propeller design are unlikely to significantly reduce this margin.

Overall draft (including propellers) is used as another criterion. All the tunnel hulls are superior to the parent. The 100% tunnel is inferior to shallower tunnels but gives greatest protection to the propellers and permits beaching. The 40% and 65% tunnels both offer some advantages and the choice depends on the tradeoffs in draft, power and propeller protection. The 65% tunnel hull offers lower draft and greater propeller protection but requires more power than the 40% tunnel hull.

ACKNOWLEDGEMENT

One of the authors of this report, Mr. W.E. Ellis, is a Defence Scientist with the Canadian Department of National Defence, on exchange to the David W. Taylor Naval Ship Research and Development Center from the Defence Research Establishment Atlantic during the period September 1975 to August 1977.

APPENDIX 1

Model 5048 with 100 Percent Tunnels

Summary of Test Conditions

Configuration 1 LCG = 3.88 ft (1.18 m) from Station 10 = 39.8% L_P

Bare Hull Resistance	Runs 341-355
Resistance Test (Appendages)	Runs 4-24
Powering Test 6.0" Propeller	Runs 26-65
Powering Test 5.25" Propeller	Runs 66-83

Configuration 2 LCG = 4.32 ft (1.32 m) from Station 10 = 44.8% L_P

Bare Hull Resistance	Runs 356-377
Resistance Test (Appendages)	Runs 84-110
Powering Test 6.0" Propeller	Runs 132-150
Powering Test 5.25" Propeller	Runs 112-129

Configuration 3 LCG = 3.39 ft (1.03 m) from Station 10 = 34.8% L_P

Bare Hull Resistance	Runs 378-392
Resistance Test (Appendages)	Runs 151-166, 270-274
Powering Test 6.0" Propeller	Runs 168-181
Powering Test 5.25" Propeller	Runs 182-185, 254-269

Configuration 4 LCG = 39.8% L_P 10° Trim Tabs

Resistance Test (Appendages)	Runs 289-305
Powering Test 6.0" Propeller	Runs 276-288

Configuration 5 LCG = 39.8% L_P 5° Trim Tabs

Resistance Test (Appendages)	Runs 326-340
Powering Test 6.0" Propeller	Runs 306-321

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Appendix 2

KEY TO COLUMN HEADINGS

VEL	-	VELOCITY, FT/SEC
DRAG	-	TOWING FORCE, LB.
HEAVE	-	BASELINE DRAFT AT TRANSOM, INCHES
TRIM	-	TRIM ANGLE CHANGE FROM REST, DEGREES
STBDT	-	THRUST ON STARBOARD SHAFT, LB.
STBDQ	-	TORQUE ON STARBOARD SHAFT, LB. IN.
PORTT	-	THRUST ON PORT SHAFT, LB.
PORTQ	-	TORQUE ON PORT SHAFT, LB. IN.
RPS	-	SHAFT ROTATIONAL SPEED, REVS/SEC
RES	-	APPENDAGED RESISTANCE FROM RESISTANCE TEST, LB.
DRAFT	-	BASELINE DRAFT / $\nabla^{\frac{1}{3}}$
FNV	-	VOLUME FROUDE NUMBER

CONFIGURATION 1 - 100 PER CENT TUNNELS - BARE HULL RESISTANCE

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
341	4.32	6.91	7.99	1.53	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.380	.575
342	7.04	13.51	8.95	2.20	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.425	.937
354	8.76	31.52	10.60	4.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.504	1.166
343	10.03	36.51	10.87	4.62	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.517	1.335
344	12.16	41.33	10.67	4.92	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.507	1.619
345	14.98	48.56	10.50	5.65	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.499	1.996
346	16.88	56.19	10.12	6.09	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.481	2.247
347	19.69	60.67	9.61	6.23	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.457	2.621
348	21.59	66.98	9.04	6.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.430	2.874
349	22.99	66.16	8.96	5.77	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.421	3.061
350	23.98	67.09	8.62	5.63	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.410	3.192
355	24.85	73.40	8.55	5.61	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.406	3.308
351	27.26	79.86	7.92	5.10	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.376	3.629
352	29.98	86.44	7.36	4.75	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.350	3.991
353	34.84	101.89	7.14	4.29	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.339	4.638

CONFIGURATION 1 - 100 PER CENT TUNNELS - RESISTANCE WITH APPENDAGES

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
15	4.40	4.38	7.97	1.77	0.00	0.00	0.00	0.00	0.00	-0.00	.379	.586
4	4.51	6.13	7.81	1.56	0.00	0.00	0.00	0.00	0.00	-0.00	.371	.600
17	7.28	16.99	9.23	2.56	0.00	0.00	0.00	0.00	0.00	-0.00	.439	.969
5	7.34	19.52	9.12	2.50	0.00	0.00	0.00	0.00	0.00	-0.00	.433	.977
19	9.77	39.42	10.85	4.61	0.00	0.00	0.00	0.00	0.00	-0.00	.515	1.301
6	10.04	38.78	10.75	4.64	0.00	0.00	0.00	0.00	0.00	-0.00	.508	1.336
22	13.19	45.42	10.31	5.23	0.00	0.00	0.00	0.00	0.00	-0.00	.490	1.756
7	13.92	49.72	10.12	5.13	0.00	0.00	0.00	0.00	0.00	-0.00	.481	1.853
8	15.64	51.53	10.34	5.83	0.00	0.00	0.00	0.00	0.00	-0.00	.491	2.082
23	16.47	55.28	10.27	6.14	0.00	0.00	0.00	0.00	0.00	-0.00	.488	2.192
24	18.85	59.41	9.77	6.41	0.00	0.00	0.00	0.00	0.00	-0.00	.464	2.509
9	18.99	59.19	9.83	6.27	0.00	0.00	0.00	0.00	0.00	-0.00	.467	2.520
20	21.79	66.12	9.09	5.88	0.00	0.00	0.00	0.00	0.00	-0.00	.432	2.901
10	21.89	62.51	8.96	5.99	0.00	0.00	0.00	0.00	0.00	-0.00	.423	2.914
11	24.79	72.73	8.34	5.50	0.00	0.00	0.00	0.00	0.00	-0.00	.396	3.300
12	27.71	81.46	7.81	5.09	0.00	0.00	0.00	0.00	0.00	-0.00	.371	3.689
13	30.42	89.47	7.71	4.93	0.00	0.00	0.00	0.00	0.00	-0.00	.368	4.049
14	32.96	99.19	7.27	4.66	0.00	0.00	0.00	0.00	0.00	-0.00	.345	4.387
16	36.55	115.66	6.93	4.30	0.00	0.00	0.00	0.00	0.00	-0.00	.329	4.865

CONFIGURATION 1 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
72	4.27	.11	8.07	1.69	3.64	5.10	3.37	4.87	11.52	5.10	.383	.568
82	6.98	1.47	9.28	2.56	9.25	11.52	9.09	11.34	18.73	15.70	.441	.929
80	8.44	1.98	10.97	4.30	17.49	21.74	17.11	20.79	25.03	30.00	.521	1.123
89	9.81	1.68	11.56	5.13	23.52	28.19	22.45	27.03	28.96	37.70	.569	1.306
81	12.46	1.20	11.29	5.77	27.05	33.43	26.08	31.51	32.80	44.80	.536	1.659
83	18.37	-2.71	10.88	7.37	37.07	47.38	35.70	46.39	41.83	58.30	.507	2.445
74	18.45	5.57	10.41	7.70	34.70	44.24	33.63	43.23	41.09	58.40	.504	2.456
75	19.82	2.72	10.17	7.63	35.81	45.81	34.42	45.80	42.85	61.70	.483	2.638
76	21.31	4.41	9.89	7.18	36.94	50.81	35.69	47.41	44.69	65.10	.470	2.837
77	22.86	2.40	9.43	6.96	40.12	53.06	38.49	51.88	47.26	68.90	.447	3.043
73	24.91	.68	8.90	6.42	41.89	57.62	40.83	55.43	49.87	73.90	.423	3.316
78	27.38	6.10	8.39	6.01	43.49	60.92	42.13	58.69	52.96	80.50	.399	3.645
79	29.68	3.48	7.90	5.87	46.08	66.72	45.07	62.22	56.05	87.10	.375	3.951

Appendix 2 - Experimental Data for 100 Per Cent Tunnel Hull

CONFIGURATION 2 - 100 PER CENT TUNNELS - BARE HULL RESISTANCE

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
356	4.17	3.16	6.45	-.34	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.307	.555
357	6.70	10.40	6.89	-.24	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.327	.892
375	7.22	14.02	7.62	.23	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.353	.961
358	8.05	21.94	8.32	.86	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.395	1.072
359	9.92	35.84	9.61	2.54	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.457	1.321
360	12.06	41.84	9.49	2.96	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.450	1.606
376	13.01	45.70	9.51	3.10	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.452	1.732
366	14.86	52.12	9.21	3.27	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.438	1.978
367	16.98	58.78	9.24	3.95	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.439	2.261
377	19.96	66.25	9.38	4.94	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.446	2.657
368	19.98	63.03	9.07	4.83	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.431	2.660
369	21.76	65.12	9.16	5.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.435	2.897
370	22.88	68.58	8.96	5.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.426	3.046
371	24.99	73.32	8.54	4.97	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.406	3.327
372	27.68	80.53	8.01	4.79	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.381	3.685
373	30.08	89.06	7.92	4.73	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.376	4.005
374	34.63	103.95	7.27	4.36	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.345	4.610

CONFIGURATION 2 - 100 PER CENT TUNNELS - RESISTANCE WITH APPENDAGES

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
84	4.29	3.70	6.67	.23	0.00	0.00	0.00	0.00	0.00	-0.00	.317	.571
105	4.43	5.18	6.80	.37	0.00	0.00	0.00	0.00	0.00	-0.00	.323	.590
106	4.90	6.45	6.92	.37	0.00	0.00	0.00	0.00	0.00	-0.00	.329	.652
107	5.96	11.66	7.11	.36	0.00	0.00	0.00	0.00	0.00	-0.00	.338	.791
85	6.63	13.73	7.20	.23	0.00	0.00	0.00	0.00	0.00	-0.00	.342	.883
108	7.42	19.[illegible]9	8.00	.86	0.00	0.00	0.00	0.00	0.00	-0.00	.380	.988
109	7.82	23.74	8.54	1.31	0.00	0.00	0.00	0.00	0.00	-0.00	.406	1.041
99	8.29	26.57	8.77	1.68	0.00	0.00	0.00	0.00	0.00	-0.00	.417	1.103
110	8.94	33.57	9.61	2.56	0.00	0.00	0.00	0.00	0.00	-0.00	.457	1.190
86	9.59	36.33	9.85	2.90	0.00	0.00	0.00	0.00	0.00	-0.00	.468	1.277
87	13.10	51.50	9.86	3.54	0.00	0.00	0.00	0.00	0.00	-0.00	.467	1.744
103	15.71	58.23	9.83	3.96	0.00	0.00	0.00	0.00	0.00	-0.00	.467	2.091
88	15.78	56.81	9.85	3.98	0.00	0.00	0.00	0.00	0.00	-0.00	.468	2.100
94	17.10	62.[illegible]0	9.75	4.46	0.00	0.00	0.00	0.00	0.00	-0.00	.463	2.276
89	18.76	65.72	9.73	5.00	0.00	0.00	0.00	0.00	0.00	-0.00	.462	2.497
95	21.28	70.[illegible]2	9.63	5.48	0.00	0.00	0.00	0.00	0.00	-0.00	.457	2.833
90	22.07	71.46	9.33	5.38	0.00	0.00	0.00	0.00	0.00	-0.00	.443	2.938
91	24.39	76.89	8.93	5.33	0.00	0.00	0.00	0.00	0.00	-0.00	.424	3.247
97	24.92	79.93	9.0[illegible]	5.18	0.00	0.00	0.00	0.00	0.00	-0.00	.428	3.317
96	25.44	79.96	8.75	5.34	0.00	0.00	0.00	0.00	0.00	-0.00	.416	3.[illegible]86
92	27.89	87.58	8.49	4.94	0.00	0.00	0.00	0.00	0.00	-0.00	.403	3.712
101	28.15	88.61	8.68	5.19	0.00	0.00	0.00	0.00	0.00	-0.00	.412	3.747
102	31.03	98.86	8.26	4.96	0.00	0.00	0.00	0.00	0.00	-0.00	.392	4.130
93	31.08	98.45	7.97	4.69	0.00	0.00	0.00	0.00	0.00	-0.00	.379	4.137
98	34.36	112.62	7.71	4.46	0.00	0.00	0.00	0.00	0.00	-0.00	.366	4.571
104	36.59	122.97	7.68	4.44	0.00	0.00	0.00	0.00	0.00	-0.00	.355	4.870

CONFIGURATION 2 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
132	4.05	-3.25	6.86	.45	3.73	4.89	3.83	4.62	9.67	3.90	.326	.539
134	7.27	-5.29	8.29	1.23	13.80	16.25	14.12	17.45	18.77	18.80	.394	.968
144	8.52	-.11	9.55	2.49	15.61	18.96	16.53	20.45	21.09	29.40	.454	1.134
135	9.95	-1.51	10.52	3.65	22.71	26.59	22.98	26.77	25.10	38.80	.500	1.324
145	12.19	-1.24	10.25	3.49	25.31	30.98	26.56	31.75	28.06	48.00	.487	1.623
147	13.43	-1.33	10.08	3.93	26.77	32.90	28.48	35.64	29.63	52.10	.479	1.788
146	14.91	-.26	10.13	4.24	29.75	36.49	31.32	39.78	31.98	56.30	.481	1.985
148	15.91	-1.76	10.37	4.57	32.66	41.15	34.34	43.32	33.74	58.90	.493	2.118
136	17.29	-2.52	10.69	5.39	34.77	43.22	37.97	47.86	35.94	62.10	.508	2.301
138	18.48	-1.38	10.32	5.59	35.60	45.34	39.69	50.31	37.43	64.60	.490	2.460
139	19.92	-1.61	10.01	5.88	36.97	47.41	40.36	54.48	39.35	67.40	.476	2.652
140	21.25	-2.49	9.86	6.07	38.11	50.96	42.83	55.92	41.09	70.10	.467	2.829
141	22.63	-1.84	9.54	6.04	38.25	50.42	42.96	57.22	42.70	73.20	.453	3.012
137	24.40	6.99	9.23	5.95	36.52	49.80	41.57	59.02	44.30	77.90	.438	3.248
142	27.31	6.77	8.75	5.67	40.01	56.57	46.33	66.14	48.47	85.90	.416	3.635
150	27.95	2.23	8.77	5.76	44.36	62.71	51.30	72.41	49.94	88.00	.417	3.720
143	29.80	-6.17	8.54	5.52	50.71	70.97	58.66	82.09	53.32	94.00	.406	3.967

CONFIGURATION 2 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
112	4.05	1.85	6.93	.52	.96	1.88	.91	1.73	11.30	3.90	.329	.539
114	7.19	1.26	8.17	1.03	8.98	11.29	9.08	11.02	18.63	16.00	.388	.957
122	8.33	1.59	9.39	2.12	14.75	18.18	14.66	18.13	23.09	27.90	.466	1.109
115	9.95	1.09	10.83	3.92	21.65	26.44	20.88	25.62	28.39	38.80	.514	1.324
123	12.49	1.08	10.52	4.00	26.33	32.00	24.40	30.00	32.03	49.00	.500	1.663
113	14.98	1.71	10.76	4.98	30.23	38.37	29.32	36.56	36.14	56.50	.511	1.994
116	17.09	1.07	10.91	5.85	33.79	43.32	33.04	41.70	39.37	61.50	.518	2.275
128	17.77	-.91	11.03	6.15	35.21	46.13	34.31	44.20	40.54	63.00	.524	2.365
118	18.40	-2.23	10.76	6.36	36.42	48.15	35.67	45.75	41.50	64.40	.511	2.449
119	19.95	3.46	10.38	6.55	35.00	44.83	33.85	46.13	42.73	67.50	.493	2.656
129	21.16	-.14	10.19	6.53	37.96	51.14	37.09	49.00	44.86	69.80	.484	2.814
120	21.50	-2.87	10.18	6.59	41.26	54.61	40.62	53.07	46.09	70.70	.484	2.862
121	22.92	.78	9.75	6.50	40.47	54.35	39.45	53.81	47.42	73.80	.463	3.051
117	24.93	4.82	9.62	6.27	40.45	56.17	39.10	54.21	49.55	79.10	.447	3.318
124	27.39	1.93	8.90	5.98	46.71	65.71	45.70	63.65	53.72	86.20	.423	3.646
125	30.02	-2.15	8.49	5.78	53.14	74.92	52.26	75.14	58.15	94.90	.403	3.996

Appendix 2 - (Cont.)

CONFIGURATION 3 - 100 PER CENT TUNNELS - BARE HULL RESISTANCE

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
378	4.11	6.59	9.07	2.49	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.431	.547
379	7.01	17.91	10.41	4.12	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.495	.933
380	8.76	35.48	11.86	6.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.564	1.166
381	9.97	41.51	11.96	6.49	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.568	1.327
382	12.93	48.99	11.37	7.17	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.540	1.721
383	15.12	56.55	11.3[illegible]	7.88	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.541	2.013
384	17.06	57.22	10.66	7.97	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.507	2.271
385	19.92	59.17	9.46	7.31	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.450	2.651
386	21.59	62.93	9.14	6.73	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.434	2.874
387	22.92	66.17	8.71	6.42	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.414	3.051
388	24.96	68.12	8.15	5.98	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.387	3.323
389	27.68	73.78	7.60	5.49	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.361	3.676
390	30.08	80.75	7.24	5.10	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.344	4.005
392	32.00	86.10	6.80	4.61	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.323	4.260
391	34.93	98.72	6.73	4.56	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.320	4.650

CONFIGURATION 3 - 100 PER CENT TUNNELS - RESISTANCE WITH APPENDAGES

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
151	4.46	5.21	9.29	3.10	0.00	0.00	0.00	0.00	0.00	-0.00	.441	.594
152	7.30	21.43	10.71	4.45	0.00	0.00	0.00	0.00	0.00	-0.00	.509	.972
270	9.78	40.60	11.80	6.27	0.00	0.00	0.00	0.00	0.00	-0.00	.563	1.302
153	9.90	43.[illegible]	11.88	6.43	0.00	0.00	0.00	0.00	0.00	-0.00	.564	1.318
154	13.23	53.17	11.40	7.32	0.00	0.00	0.00	0.00	0.00	-0.00	.542	1.761
271	14.72	55.33	11.04	7.12	0.00	0.00	0.00	0.00	0.00	-0.00	.524	1.959
164	14.96	57.67	11.01	7.49	0.00	0.00	0.00	0.00	0.00	-0.00	.523	1.991
155	16.22	61.83	10.8[illegible]	7.79	0.00	0.00	0.00	0.00	0.00	-0.00	.513	2.159
165	17.46	60.87	10.2[illegible]	7.46	0.00	0.00	0.00	0.00	0.00	-0.00	.485	2.324
156	19.39	61.74	9.2[illegible]	6.66	0.00	0.00	0.00	0.00	0.00	-0.00	.439	2.581
272	19.74	66.97	9.36	6.68	0.00	0.00	0.00	0.00	0.00	-0.00	.445	2.628
166	20.68	63.93	9.32	6.69	0.00	0.00	0.00	0.00	0.00	-0.00	.428	2.753
157	22.01	67.17	8.04	6.46	0.00	0.00	0.00	0.00	0.00	-0.00	.382	2.930
273	24.73	76.14	8.06	5.53	0.00	0.00	0.00	0.00	0.00	-0.00	.383	3.292
158	24.87	71.80	7.33	5.83	0.00	0.00	0.00	0.00	0.00	-0.00	.364	3.310
159	28.08	80.62	7.40	5.29	0.00	0.00	0.00	0.00	0.00	-0.00	.361	3.738
160	31.06	89.36	7.08	4.84	0.00	0.00	0.00	0.00	0.00	-0.00	.336	4.134
161	33.94	99.21	6.84	4.37	0.00	0.00	0.00	0.00	0.00	-0.00	.325	4.518
162	36.79	108.07	6.68	4.12	0.00	0.00	0.00	0.00	0.00	-0.00	.317	4.897

CONFIGURATION 3 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
168	4.08	-.61	9.42	3.35	3.67	4.48	3.85	5.03	10.01	4.30	.447	.543
170	7.31	-3.37	11.32	5.21	15.71	18.14	16.33	19.24	20.28	20.90	.538	.973
171	9.85	-1.42	12.09	6.96	23.12	27.24	23.41	28.84	25.50	41.80	.574	1.311
180	12.34	-3.76	11.93	7.33	30.35	36.54	31.36	39.35	29.93	51.20	.565	1.643
169	14.94	-.39	11.69	8.13	31.74	39.54	34.70	43.39	33.08	56.40	.555	1.989
172	17.04	-4.67	10.88	8.04	35.84	45.32	38.73	49.58	36.06	59.60	.517	2.268
175	18.23	-2.93	10.20	7.67	35.88	43.62	38.92	45.51	37.34	61.20	.485	2.427
176	19.89	-2.80	9.53	7.39	35.74	47.00	39.87	50.30	39.38	63.70	.453	2.648
177	21.30	-2.65	9.33	7.26	35.33	46.89	39.92	50.77	40.84	66.10	.443	2.835
178	22.81	-.50	8.82	6.86	36.17	48.72	40.85	55.96	42.74	69.20	.419	3.036
173	24.82	-.95	8.37	6.27	37.14	52.67	42.42	59.90	45.29	73.40	.395	3.304
174	27.32	-.89	7.86	5.73	40.34	58.30	46.59	66.60	48.83	79.30	.373	3.637
181	30.06	-2.09	7.44	5.20	45.12	65.57	51.81	76.78	53.05	86.60	.353	4.001

CONFIGURATION 3 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STHDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
184	3.84	-3.53	9.43	3.32	4.02	5.03	3.80	5.01	11.93	4.00	.448	.511
185	14.89	1.22	12.00	8.67	32.72	40.43	31.69	38.65	44.92	56.40	.570	1.982
182	17.23	-3.61	10.93	8.63	38.30	48.53	37.46	46.79	41.17	59.80	.519	2.293
183	24.35	2.38	8.31	6.56	37.35	50.17	36.23	49.64	48.20	72.30	.395	3.241

CONFIGURATION 3 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STRDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
258	7.29	.65	11.44	4.98	15.23	17.05	15.10	17.35	22.70	20.80	.544	.971
260	8.50	-.89	12.28	6.36	21.86	25.69	21.86	25.00	27.26	32.10	.584	1.132
259	10.02	-.44	12.66	7.17	25.19	28.74	25.31	29.19	30.05	42.60	.602	1.334
261	12.44	-.54	12.10	7.79	28.88	36.99	29.30	34.34	33.68	51.50	.575	1.656
268	14.54	-1.39	11.92	8.32	35.22	43.47	34.60	40.99	37.20	55.70	.564	1.936
257	15.01	.90	11.82	9.56	34.40	41.87	34.24	40.60	37.48	56.60	.562	1.998
262	16.99	.74	11.43	8.64	36.42	46.78	36.53	43.77	40.25	59.50	.543	2.262
263	19.92	-2.10	10.11	7.88	38.92	51.48	39.28	48.64	43.97	63.70	.480	2.652
265	22.95	-.29	8.84	7.03	38.98	52.15	40.00	50.38	47.12	69.40	.420	3.055
264	25.00	.33	8.33	6.45	41.19	57.89	42.17	53.80	49.86	73.80	.396	3.328
267	27.42	-1.65	7.97	5.83	45.12	64.56	45.47	58.96	53.20	79.50	.375	3.650
266	29.97	1.11	7.50	5.62	47.56	68.85	49.24	63.92	56.83	86.50	.356	3.990
269	35.04	3.61	6.98	4.76	56.68	83.90	58.85	78.62	64.51	102.30	.332	4.665

Appendix 2 - (Cont.)

CONFIGURATION 6 - 100 PER CENT TUNNELS - RESISTANCE WITH APPENDAGES

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
289	4.29	5.11	7.5[illegible]	1.22	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.361	.571
290	7.29	16.87	8.61	1.82	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.409	.971
291	8.37	26.53	9.36	2.60	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.445	1.114
292	9.85	36.56	10.00	3.49	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.475	1.311
293	12.00	40.92	9.61	3.66	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.457	1.598
302	13.81	44.57	9.63	3.81	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.448	1.839
298	14.80	49.73	9.92	3.62	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.429	1.970
294	14.88	49.40	8.96	3.69	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.426	1.981
295	17.20	56.86	9.01	4.08	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.428	2.290
296	19.75	65.53	8.76	4.21	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.416	2.629
297	21.21	70.39	8.36	4.17	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.397	2.824
304	21.48	70.47	8.33	4.06	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.394	2.860
299	23.03	76.43	7.96	3.83	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.378	3.066
300	24.60	81.39	7.56	3.71	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.359	3.275
305	30.15	107.53	6.97	3.29	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.331	4.014
303	34.63	136.13	6.84	3.08	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.325	4.610

CONFIGURATION 6 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS 10 DEG TRIM TABS

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
276	4.10	-.53	7.60	1.26	4.46	4.06	4.44	4.68	10.18	4.30	.364	.546
278	6.76	-.38	8.24	1.56	9.78	10.58	10.32	12.20	16.25	14.70	.392	.900
284	8.18	-1.38	9.65	2.84	16.70	19.09	17.84	20.69	21.14	25.80	.459	1.089
279	9.99	-.03	10.18	3.78	20.24	23.25	21.43	25.80	24.08	34.30	.484	1.318
282	12.51	3.00	9.90	4.04	24.46	30.44	26.77	32.06	27.99	42.50	.470	1.665
277	14.96	1.18	9.70	4.17	29.77	36.89	32.66	39.36	31.62	49.60	.461	1.989
280	17.18	.72	9.38	4.42	33.94	42.73	37.29	46.26	35.06	56.60	.446	2.287
281	19.39	-1.74	9.01	4.57	37.79	48.58	42.17	53.57	38.36	63.50	.428	2.581
286	21.22	.65	8.82	4.69	38.54	49.77	43.59	54.70	40.53	69.30	.418	2.825
283	23.03	1.37	8.28	4.53	40.56	55.90	46.32	60.14	42.94	75.20	.393	3.066
285	24.91	.53	8.2[illegible]	4.41	44.81	62.52	51.20	66.59	45.71	81.70	.390	3.303
287	27.25	1.43	7.88	4.21	49.35	65.32	56.60	73.89	49.25	92.00	.374	3.628

CONFIGURATION 5 - 100 PER CENT TUNNELS - RESISTANCE WITH APPENDAGES

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
326	4.07	3.82	7.76	1.28	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.369	.542
327	7.22	16.26	8.87	1.77	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.407	.961
328	8.53	27.[illegible]3	9.69	2.92	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.460	1.136
329	9.83	36.61	10.21	3.77	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.485	1.309
338	10.95	39.44	9.84	3.88	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.468	1.458
330	12.78	41.44	9.76	4.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.464	1.701
331	15.10	53.23	9.64	4.18	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.449	2.010
332	16.82	54.72	9.32	4.59	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.443	2.239
333	19.79	65.21	8.72	4.76	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.414	2.635
334	21.56	67.49	8.73	4.88	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.415	2.868
335	22.92	71.78	8.39	4.80	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.399	3.051
336	25.02	78.59	7.87	4.36	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.374	3.331
337	27.38	87.32	7.65	4.09	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.354	3.645
339	29.88	97.55	7.24	3.84	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.344	3.978
340	35.04	123.64	6.83	3.54	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	.325	4.665

CONFIGURATION 5 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS 5 DEG TRIM TABS

RUN	VEL	DRAG	HEAVE	TRIM	STBDT	STBDQ	PORTT	PORTQ	RPS	RES	DRAFT	FNV
306	4.10	-1.76	7.65	1.15	3.69	4.88	4.03	4.58	10.07	4.30	.354	.546
315	8.32	-.51	9.89	3.10	16.79	20.84	17.56	20.08	21.41	26.90	.469	1.108
310	9.82	2.44	10.70	4.12	20.27	24.16	21.40	25.18	24.26	34.50	.508	1.307
317	9.96	-1.[illegible]9	10.29	3.88	21.22	25.21	22.34	25.77	24.46	34.80	.489	1.326
313	11.88	1.17	10.15	4.22	22.50	27.60	24.65	29.08	26.92	42.60	.482	1.582
307	15.00	-1.61	10.07	4.82	31.46	39.93	33.62	39.69	32.51	52.00	.479	1.997
311	17.10	-2.88	10.24	5.48	35.13	42.96	37.76	46.07	35.58	57.20	.487	2.277
312	19.53	.89	9.72	5.58	36.11	47.55	39.75	50.22	38.50	62.60	.462	2.600
318	21.22	-.30	9.22	5.50	38.75	50.90	42.81	54.59	40.82	67.00	.438	2.825
314	22.80	-1.55	8.76	5.32	39.83	54.10	44.47	57.26	42.86	71.50	.416	3.035
316	24.61	-.26	8.32	5.09	42.32	60.24	47.66	61.74	45.37	77.20	.395	3.276
319	27.26	.35	8.07	4.94	47.37	65.54	53.44	70.39	49.15	86.50	.383	3.629
320	30.01	-.37	7.61	4.39	53.06	74.75	60.22	80.91	53.32	98.20	.352	3.995
321	34.48	.78	6.89	4.00	63.62	92.60	72.57	100.40	60.09	120.00	.327	4.590

Appendix 2 - (Cont.)

CONFIGURATION 1 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

MODEL LENGTH = 6.600 FT MODEL WETTED SURFACE = 18.920 SQ FT MODEL DISPLACEMENT = 341. LBS LINEAR RATIO = 1.000
NU-MODEL (E+5) = 1.02100 NU-SHIP (E+5) = 1.02100 RHO-MODEL = 1.9607 RHO-SHIP = 1.9607
MODEL PROPELLER DIAMETER = 5.250 IN CORRELATION ALLOWANCE =0.00000 ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EM	ERR
4.27	.040	.353	.112	646.1	.8412	.3705	.804	.956	.10004	.614	.730	.712	.585	.745	.809
6.98	.199	.432	.461	1161.2	.8243	.3780	.793	.962	.08854	.732	.888	.776	.574	.807	.934
8.44	.460	.417	1.105	1537.2	.7530	.3928	.759	1.008	.08151	.701	.931	.810	.552	.804	.939
9.81	.672	.417	1.613	1764.5	.7625	.3872	.770	1.010	.08834	.734	.962	.784	.559	.776	.961
12.46	1.015	.484	2.097	1984.8	.8609	.3472	.852	.989	.08067	.815	.947	.821	.609	.830	.957
18.37	1.947	.550	3.543	2478.8	1.0163	.2836	.984	.968	.06997	.930	.915	.838	.683	.866	.930
18.45	1.959	.512	3.824	2532.0	.9993	.2936	.963	.964	.07087	.921	.981	.778	.672	.807	.945
19.82	2.223	.565	3.935	2602.1	1.0446	.2719	1.008	.965	.06719	.961	.919	.840	.695	.870	.935
21.31	2.522	.537	4.695	2755.5	1.0606	.2659	1.021	.963	.06752	.957	.902	.808	.701	.839	.913
22.86	2.864	.583	4.912	2860.9	1.0958	.2494	1.056	.964	.06310	1.005	.917	.846	.717	.878	.926
24.91	3.347	.617	5.421	2998.8	1.1392	.2326	1.092	.958	.06048	1.034	.907	.885	.733	.924	.912
27.38	4.007	.611	6.561	3235.6	1.1605	.2217	1.115	.961	.05826	1.058	.911	.869	.742	.905	.910
29.68	4.700	.653	7.198	3394.8	1.1990	.2069	1.146	.956	.05535	1.089	.909	.915	.754	.957	.905

CONFIGURATION 2 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

MODEL LENGTH = 6.600 FT MODEL WETTED SURFACE = 18.920 SQ FT MODEL DISPLACEMENT = 341. LBS LINEAR RATIO = 1.000
NU-MODEL (F+5) = .98600 NU-SHIP (F+5) = .98600 RHO-MODEL = 1.9602 RHO-SHIP = 1.9602
MODEL PROPELLER DIAMETER = 5.250 IN CORRELATION ALLOWANCE =0.00000 ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EM	ERR
4.05	.029	.423	[illegible]	752.1	.7385	.1560	1.256	1.701	.04800	1.169	1.583	1.108	.782	.651	.831
7.19	.209	.477	.438	1148.5	.8585	.3725	.800	.932	.08708	.747	.870	.816	.578	.876	.942
8.33	.423	.492	.860	1413.3	.8087	.3913	.762	.942	.09161	.700	.866	.895	.554	.949	.935
9.95	.702	.481	1.458	1719.4	.7936	.3710	.803	1.012	.08632	.755	.951	.887	.580	.876	.947
12.49	1.113	.573	1.943	1915.3	.8851	.3471	.852	.962	.08067	.815	.921	.945	.609	.982	.957
14.98	1.539	.575	2.675	2148.4	.9388	.3214	.905	.964	.07680	.856	.912	.920	.640	.955	.941
17.09	1.911	.587	3.253	2374.1	.9872	.3025	.944	.957	.07316	.896	.907	.904	.662	.945	.939
17.77	2.035	.594	3.424	2422.7	1.0059	.2927	.965	.959	.07255	.902	.897	.919	.673	.959	.921
18.40	2.154	.604	3.567	2466.8	1.0230	.2870	.977	.955	.07150	.914	.893	.924	.679	.968	.919
19.95	2.448	.623	3.928	2549.7	1.0524	.2691	1.014	.964	.06727	.960	.912	.930	.698	.965	.925
21.14	2.683	.629	4.267	2690.2	1.0777	.2593	1.035	.960	.06595	.974	.904	.932	.708	.971	.915
21.50	2.766	.612	4.517	2737.0	1.0773	.2633	1.027	.953	.06629	.970	.901	.899	.704	.943	.922
22.92	3.075	.623	4.940	2852.8	1.1018	.2488	1.057	.960	.06403	.995	.903	.914	.718	.952	.911
24.93	3.585	.643	5.573	3017.9	1.1329	.2331	1.090	.963	.06101	1.028	.907	.934	.732	.970	.906
27.39	4.293	.633	6.777	3240.2	1.1593	.2257	1.106	.954	.05995	1.039	.897	.912	.739	.955	.897
30.02	5.180	.638	8.115	3471.5	1.1859	.2144	1.131	.953	.05836	1.057	.891	.921	.748	.966	.884

CONFIGURATION 2 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS

MODEL LENGTH = 6.600 FT MODEL WETTED SURFACE = 18.920 SQ FT MODEL DISPLACEMENT = 341. LBS LINEAR RATIO = 1.000
NU-MODEL (F+5) = .98600 NU-SHIP (F+5) = .98600 RHO-MODEL = 1.9602 RHO-SHIP = 1.9602
MODEL PROPELLER DIAMETER = 6.000 IN CORRELATION ALLOWANCE =0.00000 ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EM	ERR
4.05	.029	.658	.044	490.3	.9911	.2520	.787	.794	.05714	.713	.719	.946	.617	1.191	.896
7.27	.249	.559	[illegible]	1043.8	.8364	.2943	.700	.837	.06044	.671	.803	.863	.564	1.030	.962
8.52	.455	.578	.788	1263.9	.8089	.2945	.700	.865	.06021	.674	.834	.918	.564	1.061	.966
9.95	.702	.576	1.218	1488.1	.8024	.2918	.706	.879	.05703	.714	.898	.882	.568	1.003	1.012
12.19	1.066	.655	1.624	1671.0	.8754	.2661	.758	.866	.05373	.755	.863	.949	.600	1.096	.996
13.43	1.272	.678	1.876	1765.0	.9131	.2541	.783	.858	.05266	.769	.842	.967	.614	1.128	.979
14.91	1.526	.661	2.309	1916.3	.9337	.2432	.805	.863	.05065	.794	.851	.926	.627	1.074	.982
15.91	1.704	.650	2.622	2048.4	.9506	.2370	.818	.861	.04996	.803	.844	.905	.634	1.051	.975
17.29	1.952	.666	2.975	2134.0	.9723	.2255	.842	.866	.04725	.836	.860	.888	.646	1.026	.991
18.48	2.171	.652	3.327	2233.7	.9928	.2171	.860	.866	.04607	.851	.857	.876	.654	1.012	.985
19.92	2.441	.657	3.718	2347.5	1.0183	.2014	.892	.876	.04435	.873	.857	.892	.669	1.018	.964
21.25	2.708	.673	4.124	2445.4	1.0428	.1921	.912	.874	.04246	.896	.859	.897	.677	1.026	.970
22.63	3.012	.707	4.259	2547.9	1.0658	.1793	.938	.881	.03974	.930	.872	.924	.688	1.049	.982
24.40	3.456	.682	5.069	2712.0	1.0796	.1714	.955	.885	.03922	.936	.867	.908	.691	1.027	.961
27.31	4.265	.710	6.004	2941.3	1.1142	.1553	.989	.888	.03642	.970	.871	.940	.700	1.059	.959
27.95	4.472	.678	6.596	3012.0	1.1135	.1589	.981	.881	.03726	.960	.862	.897	.698	1.018	.954
29.80	5.093	.685	7.436	3171.9	1.1274	.1529	.994	.882	.03593	.976	.866	.898	.701	1.018	.960

CONFIGURATION 3 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS

MODEL LENGTH = 6.600 FT MODEL WETTED SURFACE = 18.920 SQ FT MODEL DISPLACEMENT = 341. LBS LINEAR RATIO = 1.000
NU-MODEL (F+5) = .98600 NU-SHIP (F+5) = .98600 RHO-MODEL = 1.9602 RHO-SHIP = 1.9602
MODEL PROPELLER DIAMETER = 6.000 IN CORRELATION ALLOWANCE =0.00000 ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EM	ERR
4.08	.032	.433	.074	569.7	.8594	.2865	.716	.834	.06154	.657	.765	.880	.575	.815	.924
7.31	.278	.465	.598	1150.6	.7558	.3010	.687	.909	.05903	.689	.912	.757	.556	.834	1.003
9.85	.749	.573	1.306	1514.1	.7807	.2909	.707	.906	.05807	.701	.898	.921	.569	1.016	.991
12.34	1.149	.578	1.987	[illegible]	.8423	.2733	.744	.883	.05644	.722	.857	.891	.591	1.009	.969
14.94	1.532	.589	[illegible]	1961.0	.9050	.2671	.797	.881	.05161	.782	.864	.854	.622	.970	.976
17.04	1.847	.618	2.987	2121.1	.9640	.2258	.842	.873	.04830	.823	.854	.862	.646	.987	.970
18.23	2.029	.677	2.997	2214.0	.9851	.2140	.866	.877	.04262	.894	.905	.857	.657	.978	1.053
19.89	2.304	.669	3.476	[illegible]	1.0205	.1965	.907	.888	.04193	.903	.884	.880	.675	.990	.992
21.30	2.560	.704	3.636	2629.0	1.0523	.1802	.937	.890	.03915	.937	.890	.914	.686	1.026	1.000
22.81	2.870	.679	4.227	2560.4	1.0690	.1714	.955	.893	.03886	.940	.880	.905	.691	1.013	.969
24.82	3.312	.692	4.790	2710.4	1.0989	.1571	.985	.896	.03713	.962	.875	.935	.699	1.042	.949
27.32	3.939	.686	5.741	[illegible]	1.1214	.1478	1.005	.896	.03546	.982	.876	.922	.703	1.030	.948
30.06	4.733	.674	7.022	3159.2	1.1382	.1385	1.024	.900	.03405	.999	.878	.915	.705	1.017	.940

Appendix 3 - Propulsive Characteristics for 100 Per Cent Tunnel Hull

CONFIGURATION 3 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

MODEL LENGTH = 6.600 FT   MODEL WETTED SURFACE = 18.920 SQ FT   MODEL DISPLACEMENT = 341. LBS   LINEAR RATIO = 1.000
NU-MODEL (E+5) - 1.02600   NU-SHIP (E+5) = 1.02600   RHO-MODEL = 1.9620   RHO-SHIP = 1.9620
MODEL PROPELLER DIAMETER = 5.250 IN   CORRELATION ALLOWANCE =0.00000   ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EH	ERR
7.29	.276	.356	.775	1377.2	.7259	.4133	.718	.989	.08921	.725	.998	.864	.525	.672	1.008
8.50	.496	.391	1.270	1620.3	.7194	.4058	.733	1.019	.08972	.719	1.000	.755	.535	.741	.986
10.02	.776	.475	1.635	1796.8	.7648	.3877	.769	1.006	.08475	.772	1.009	.852	.558	.847	1.003
12.44	1.165	.516	2.258	2014.1	.8470	.3554	.835	.986	.08307	.789	.932	.894	.599	.908	.949
14.54	1.473	.528	2.788	2191.6	.9098	.3431	.860	.945	.07960	.826	.908	.846	.614	.895	.960
15.01	1.545	.516	2.995	2258.8	.9113	.3417	.863	.947	.07813	.842	.924	.813	.616	.859	.975
16.99	1.838	.522	3.522	2423.9	.9613	.3148	.919	.955	.07435	.883	.918	.805	.648	.843	.956
19.92	2.307	.572	4.037	2615.3	1.0446	.2772	.997	.955	.06784	.954	.913	.841	.689	.881	.941
22.95	2.896	.633	4.578	2824.3	1.1144	.2469	1.061	.952	.06109	1.027	.922	.882	.720	.927	.949
25.00	3.355	.630	5.328	2994.8	1.1448	.2338	1.089	.951	.05963	1.043	.911	.881	.732	.926	.929
27.42	3.963	.648	6.119	3177.1	1.1836	.2202	1.118	.945	.05736	1.068	.902	.896	.743	.948	.919
29.97	4.713	.647	7.283	3419.5	1.2020	.2100	1.140	.948	.05476	1.096	.912	.882	.751	.930	.926
35.04	6.517	.629	10.356	3899.9	1.2322	.1972	1.167	.947	.05249	1.121	.909	.854	.761	.902	.918

CONFIGURATION 3 - 100 PER CENT TUNNELS - 5.25 INCH PROPELLERS

MODEL LENGTH = 6.600 FT   MODEL WETTED SURFACE = 18.920 SQ FT   MODEL DISPLACEMENT = 341. LBS   LINEAR RATIO = 1.000
NU-MODEL (E+5) = .98600   NU-SHIP (E+5) = .98600   RHO-MODEL = 1.9602   RHO-SHIP = 1.9602
MODEL PROPELLER DIAMETER = 5.250 IN   CORRELATION ALLOWANCE =0.00000   ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EH	ERR
3.84	.028	.502	.056	604.2	.8716	.2852	.980	1.125	.07585	.867	.994	.963	.681	.856	.861
14.89	1.527	.440	3.468	2704.9	.7538	.2249	1.108	1.470	.05250	1.120	1.486	.857	.739	.583	1.022
17.23	1.873	.538	3.485	2429.2	.9727	.3035	.942	.969	.07316	.896	.921	.837	.661	.864	.941
24.35	3.201.	.674	4.750	2914.5	1.1458	.2245	1.109	.968	.05773	1.064	.928	.950	.740	.982	.928

CONFIGURATION 4 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS 10 DEG TRIM TABS

MODEL LENGTH = 6.800 FT   MODEL WETTED SURFACE = 18.920 SQ FT   MODEL DISPLACEMENT = 341. LBS   LINEAR RATIO = 1.000
NU-MODEL (E+5) = 1.02600   NU-SHIP (E+5) = 1.02600   RHO-MODEL = 1.9620   RHO-SHIP = 1.9620
MODEL PROPELLER DIAMETER = 6.000 IN   CORRELATION ALLOWANCE =0.00000   ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EH	ERR
4.10	.032	.414	.077	567.1	.8360	.3374	.612	.731	.05894	.690	.824	.543	.505	.743	1.105
6.76	.181	.530	.341	967.0	.8389	.3076	.673	.802	.05816	.700	.834	.750	.547	.935	1.037
8.18	.386	.512	.749	1247.1	.7871	.3094	.669	.850	.05955	.683	.867	.787	.544	.925	1.018
9.90	.617	.550	1.123	1444.4	.8225	.2957	.697	.848	.05747	.709	.862	.816	.562	.962	1.016
12.51	.967	.531	1.822	1717.1	.8742	.2744	.741	.848	.05547	.734	.839	.771	.590	.909	.989
14.94	1.347	.570	2.363	1910.5	.9364	.2572	.777	.828	.05225	.774	.825	.776	.611	.937	.996
17.18	1.768	.586	3.017	2112.2	.9761	.2374	.818	.838	.04937	.810	.830	.785	.633	.937	.988
19.39	2.239	.616	3.636	2288.3	1.0168	.2192	.855	.841	.04678	.842	.828	.812	.652	.966	.978
21.22	2.676	.656	4.074	2437.4	1.0447	.2048	.885	.847	.04338	.885	.847	.836	.666	.987	.999
23.03	3.149	.651	4.860	2587.6	1.0680	.1940	.908	.850	.04308	.888	.832	.850	.675	1.000	.964
24.81	3.685	.651	5.658	2746.7	1.0839	.1880	.920	.849	.04210	.900	.831	.845	.680	.996	.962
27.25	4.558	.686	6.640	2965.3	1.1027	.1797	.938	.850	.03927	.935	.848	.855	.686	1.005	.995

CONFIGURATION 5 - 100 PER CENT TUNNELS - 6.0 INCH PROPELLERS 5 DEG TRIM TABS

MODEL LENGTH = 6.800 FT   MODEL WETTED SURFACE = 18.920 SQ FT   MODEL DISPLACEMENT = 341. LBS   LINEAR RATIO = 1.000
NU-MODEL (E+5) = 1.02600   NU-SHIP (E+5) = 1.02600   RHO-MODEL = 1.9620   RHO-SHIP = 1.9620
MODEL PROPELLER DIAMETER = 6.000 IN   CORRELATION ALLOWANCE =0.00000   ITTC FRICTION USED

VM(FPS)	EHP	EHP/SHP	SHP	RPM	JA	KT	JT	1-WT	KQ	JQ	1-WQ	1-T	EP	EH	ERR
4.10	.032	.532	.060	546.9	.8997	.2678	.755	.839	.05685	.716	.796	.788	.598	.939	.946
8.32	.407	.500	.815	1276.9	.7819	.3035	.682	.872	.06034	.673	.860	.798	.552	.915	.988
9.82	.616	.493	1.250	1440.2	.7908	.2964	.696	.880	.05823	.699	.884	.769	.562	.874	1.004
9.96	.630	.552	1.142	1451.4	.8223	.2935	.702	.854	.05735	.710	.864	.824	.565	.965	1.011
11.88	.920	.612	1.503	1628.6	.8753	.2683	.754	.861	.05365	.757	.864	.879	.597	1.020	1.004
15.00	1.418	.597	2.376	1934.0	.9307	.2477	.796	.855	.05065	.796	.853	.824	.622	.963	.997
17.10	1.778	.625	2.845	2107.1	.9730	.2294	.834	.856	.04690	.841	.863	.824	.642	.962	1.012
19.53	2.223	.610	3.642	2318.3	1.0169	.2102	.874	.865	.04507	.864	.854	.813	.661	.941	.981
21.22	2.585	.634	4.079	2446.6	1.0438	.1991	.897	.862	.04295	.890	.855	.825	.671	.957	.987
22.80	2.966	.668	4.438	2559.1	1.0641	.1949	.927	.867	.04083	.916	.857	.867	.682	1.000	.979
24.61	3.456	.658	5.250	2720.2	1.0857	.1779	.941	.867	.04022	.924	.851	.861	.687	.993	.964
27.26	4.287	.671	6.388	2951.6	1.1083	.1736	.957	.863	.03831	.947	.855	.855	.692	.990	.980
30.01	5.358	.681	7.870	3146.7	1.1265	.1621	.975	.865	.03715	.962	.854	.870	.697	1.006	.971
34.48	7.523	.677	11.115	3610.1	1.1361	.1544	.991	.864	.03643	.970	.847	.875	.700	1.013	.954

Appendix 3 - (Cont.)

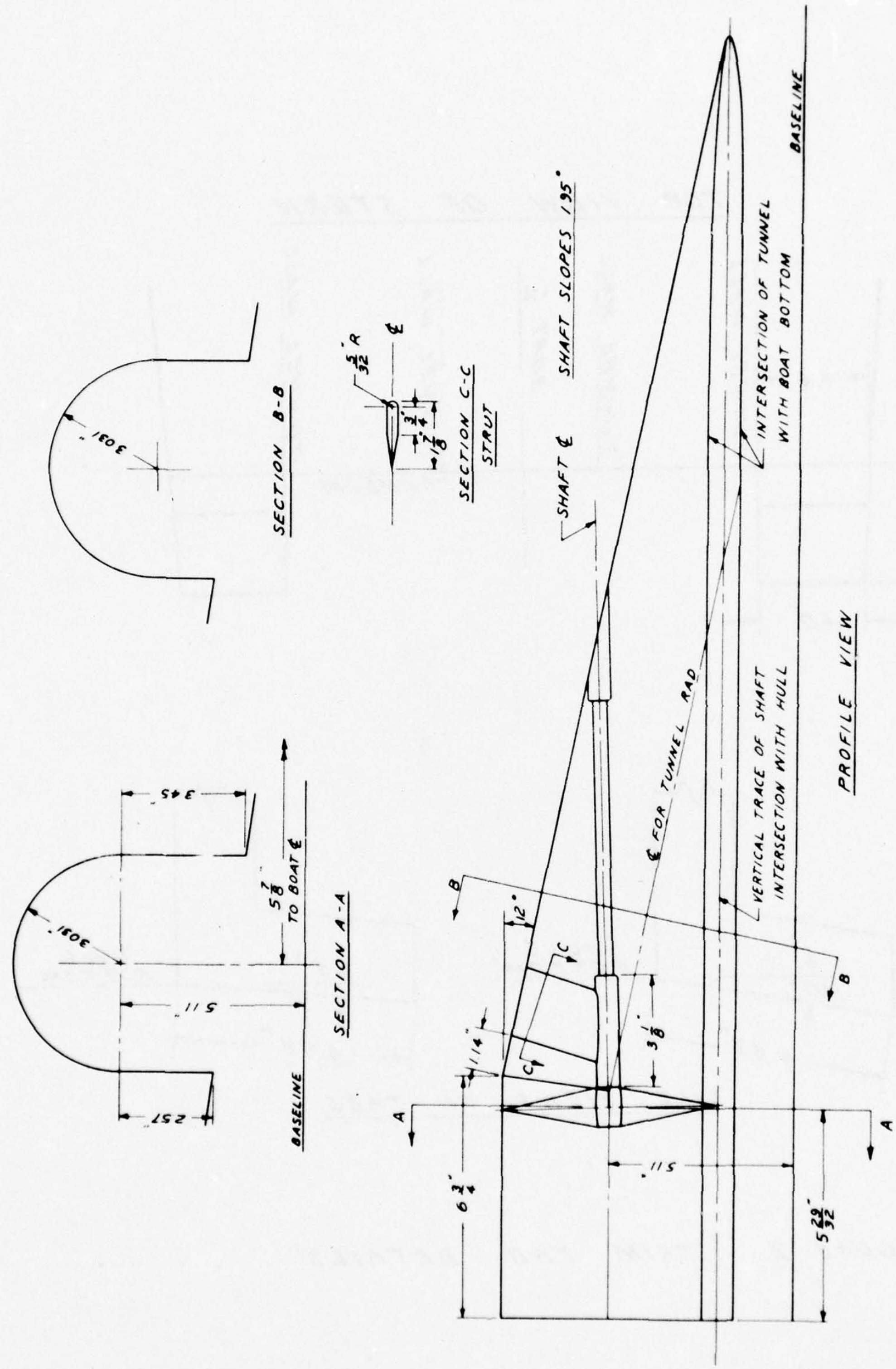


Figure 1 - Details of 100 Per Cent Tunnel

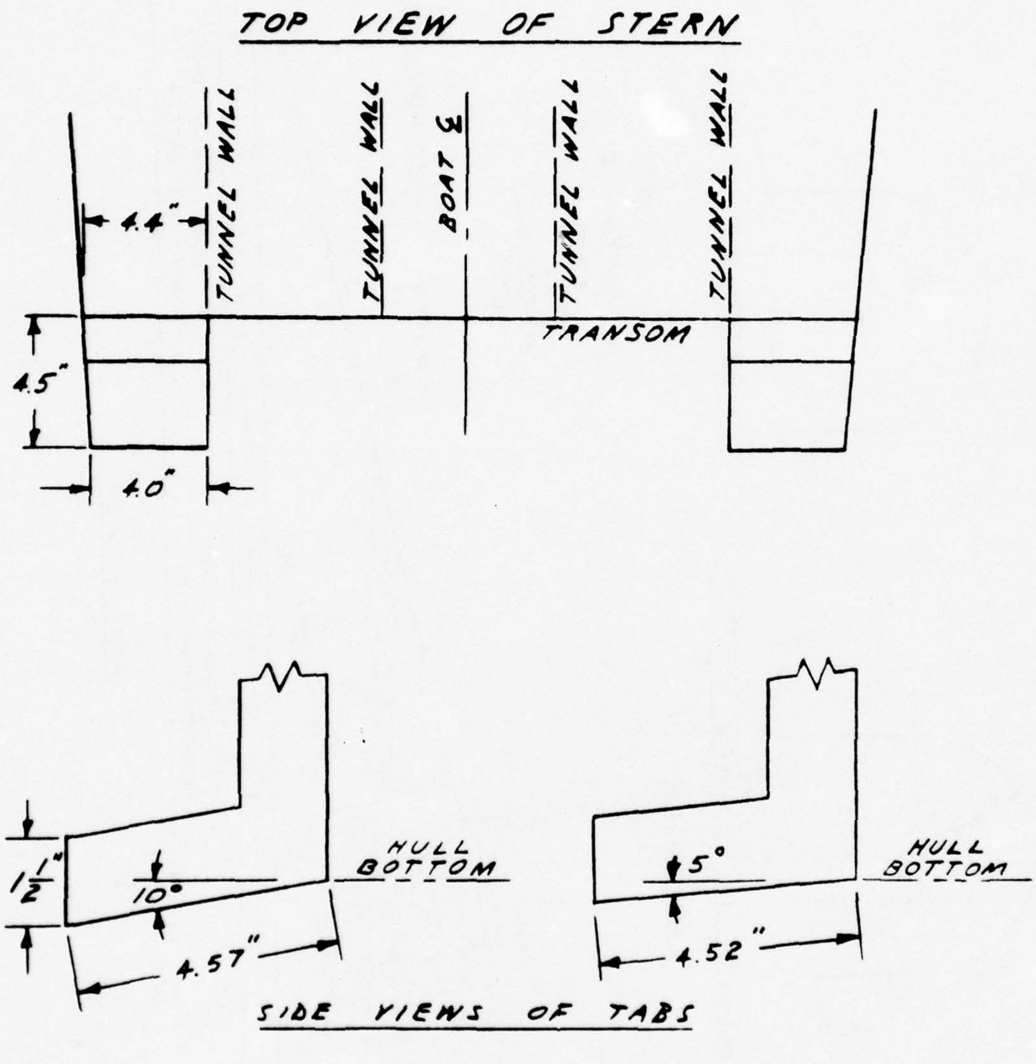
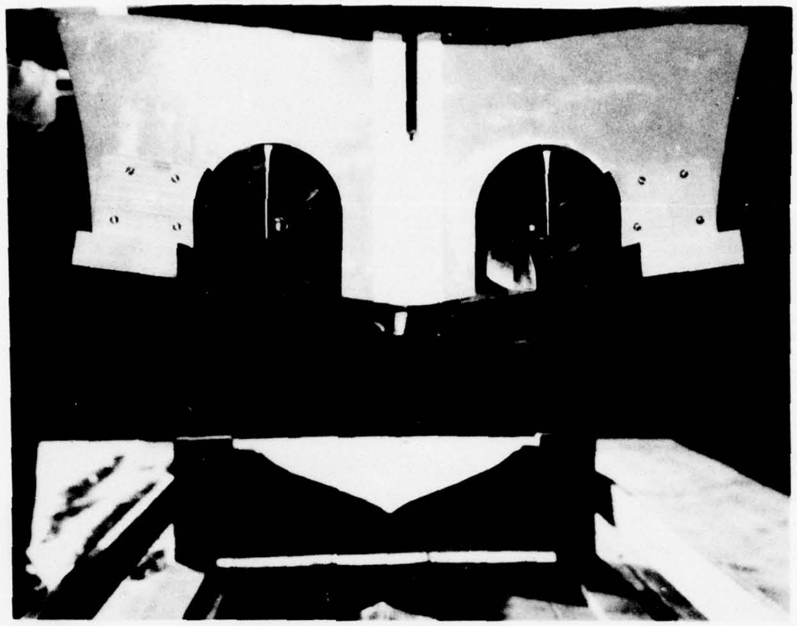
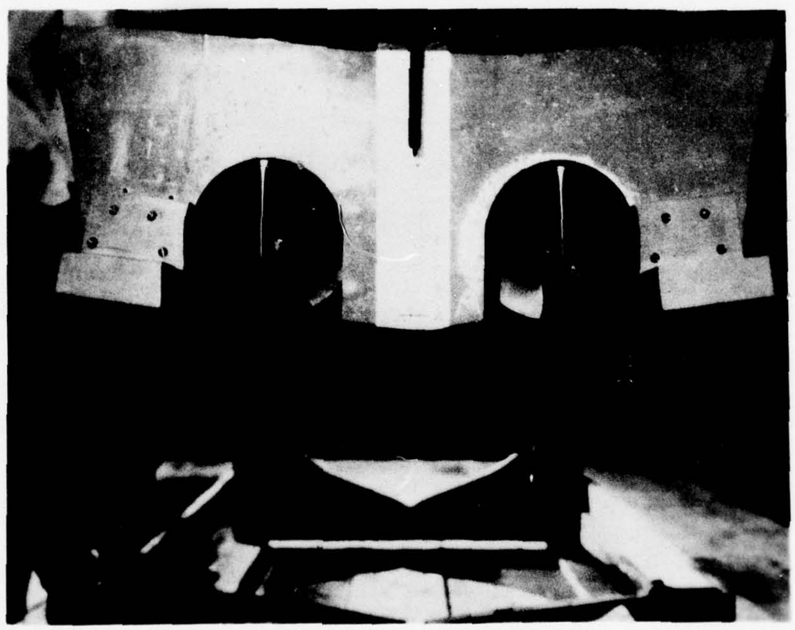


FIGURE 2. TRIM TAB DETAILS



5° Trim Tabs



10° Trim Tabs

Figure 3 - Stern Views Showing Trim Tabs, 6 Inch Propellers and Appendages

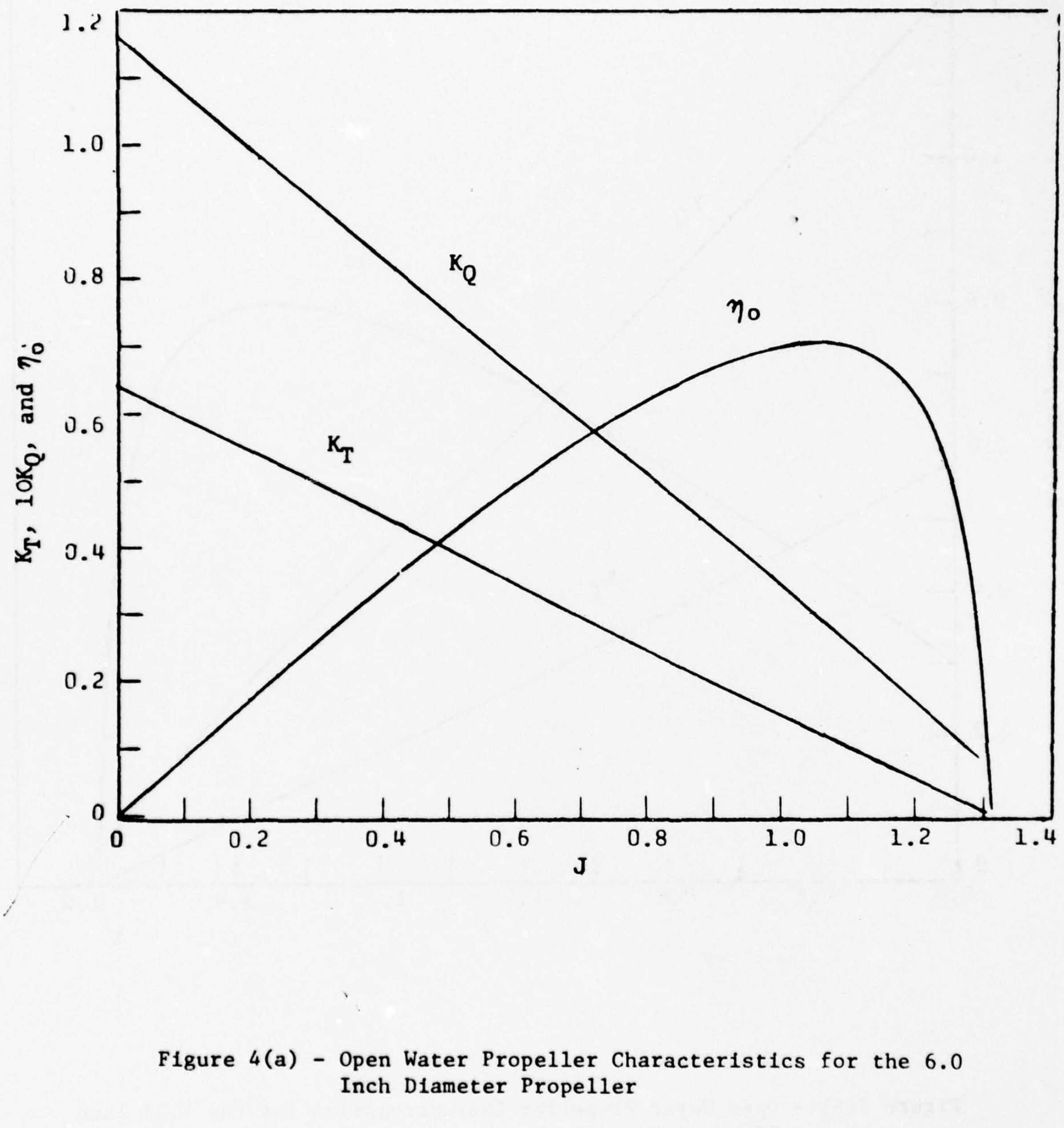


Figure 4(a) - Open Water Propeller Characteristics for the 6.0 Inch Diameter Propeller

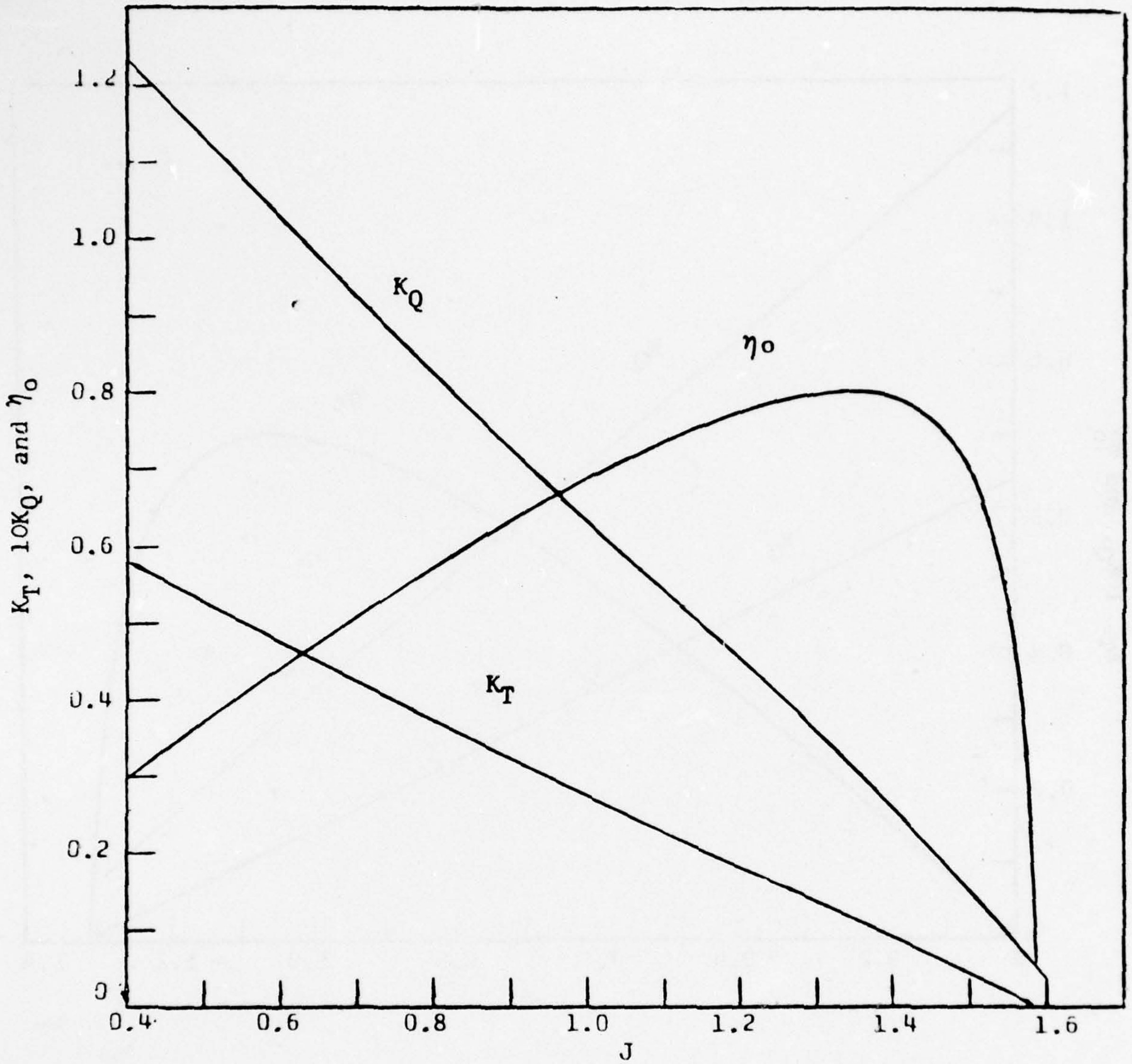


Figure 4(b) - Open Water Propeller Characteristics for the 5.25 Inch Diameter Propeller

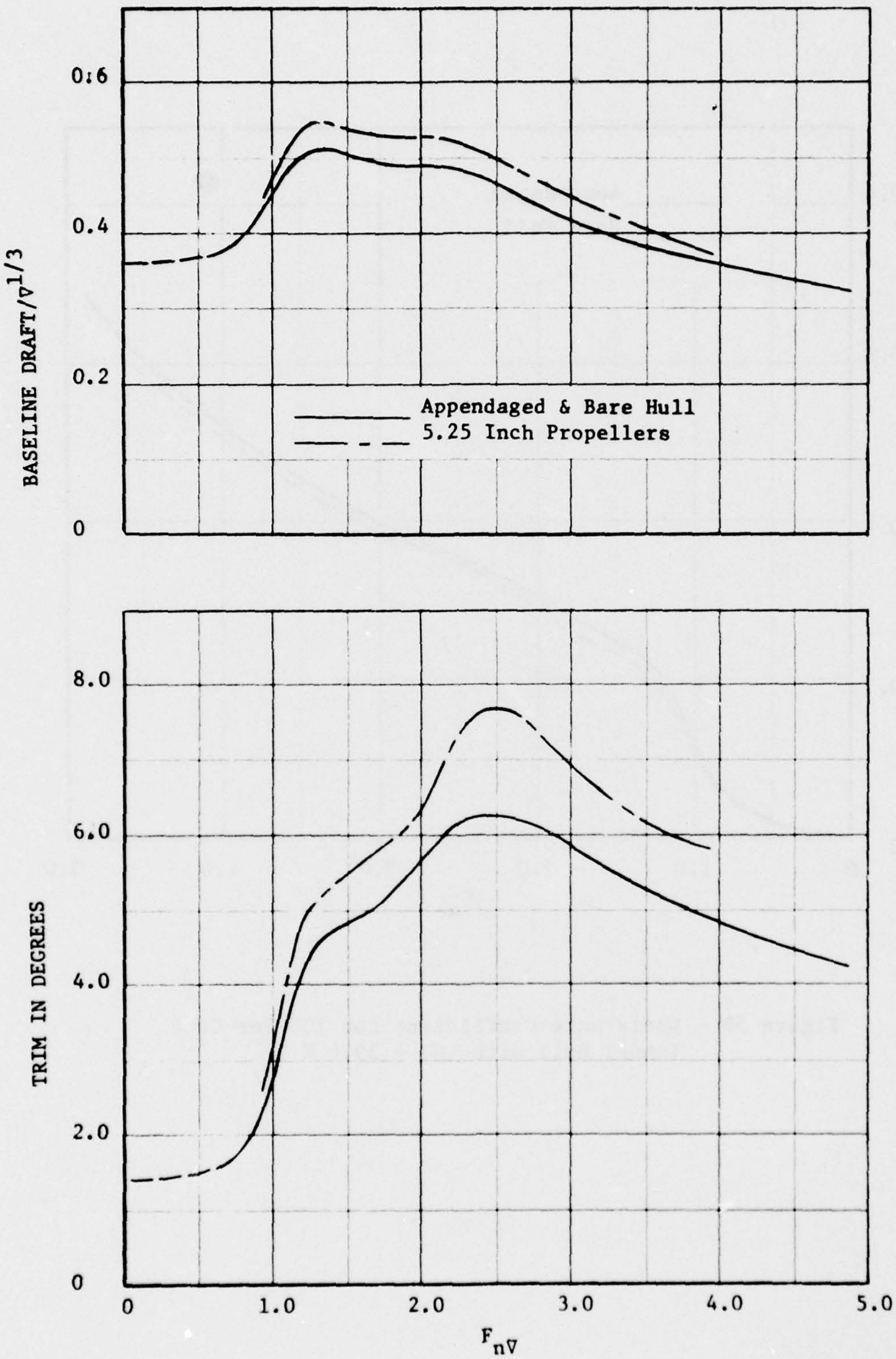


Figure 5A - Trim Angle and Baseline Draft of 100 Per Cent Tunnel Hull with LCG = 39.8% L_p

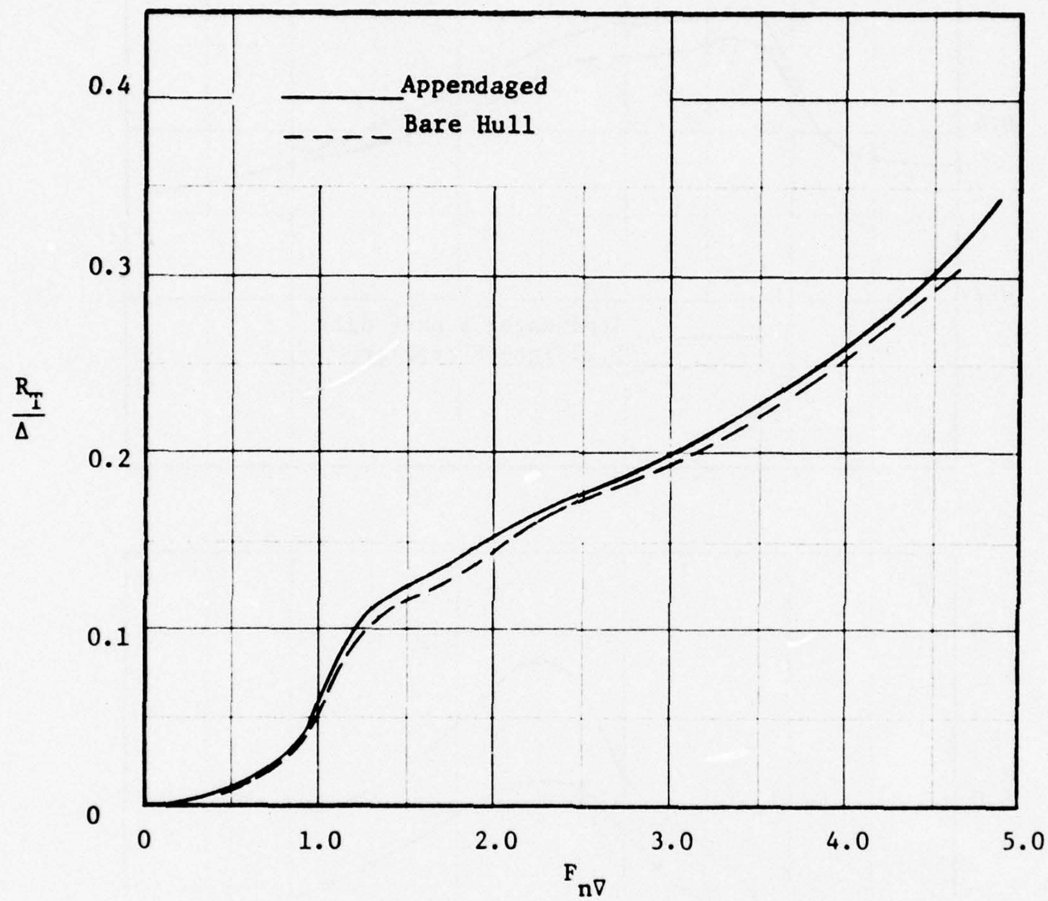


Figure 5B - Resistance Coefficient for 100 Per Cent Tunnel Hull with LCG = 39.8 % L_p

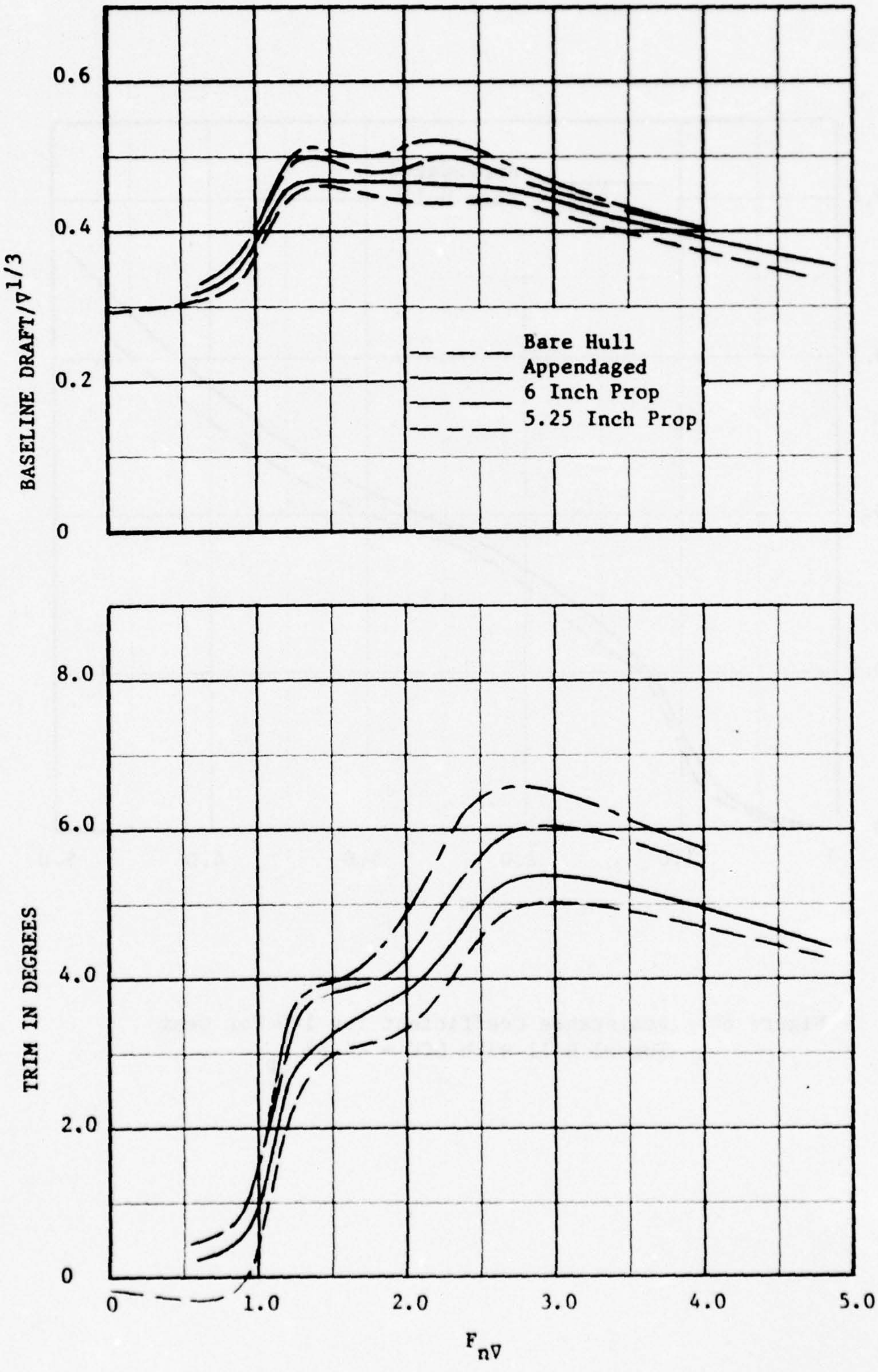


Figure 6A - Trim Angle and Baseline Draft of 100 Per Cent Tunnel Hull with LCG = 44.8% L_p

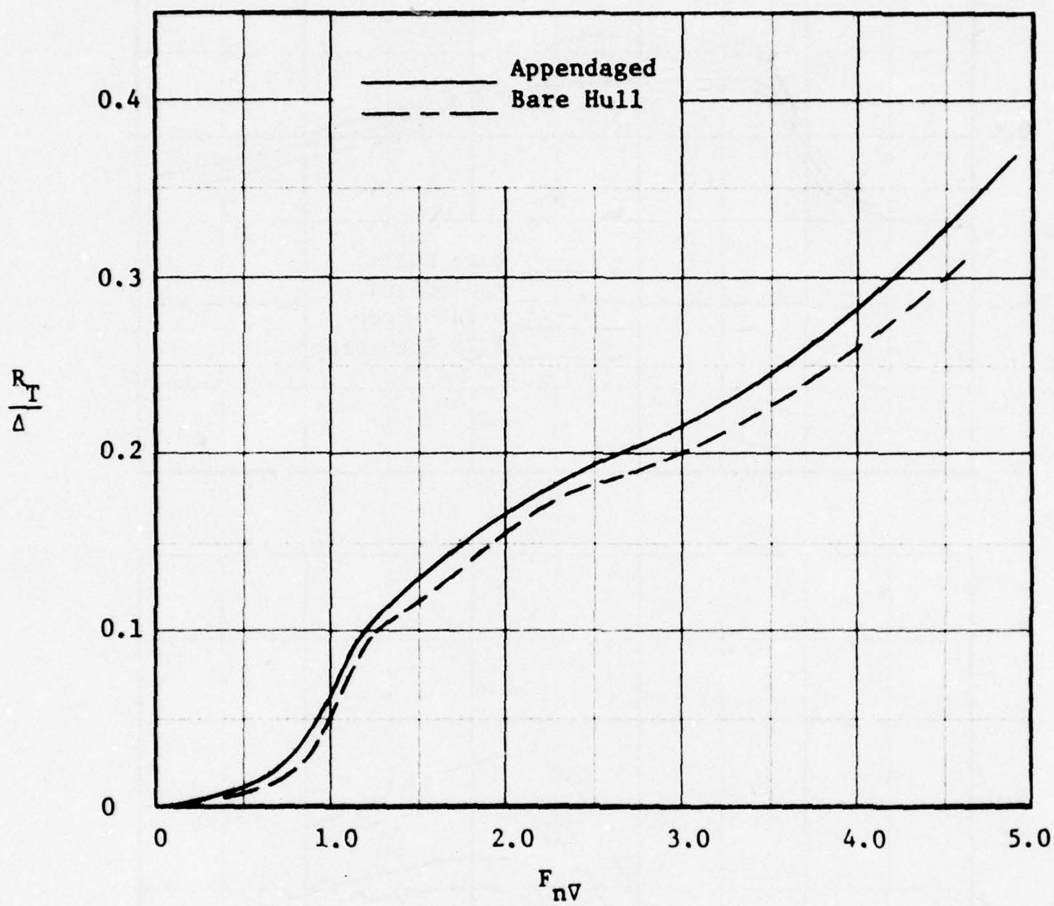


Figure 6B - Resistance Coefficient for 100 Per Cent Tunnel Hull with LCG = 44.8% L_p

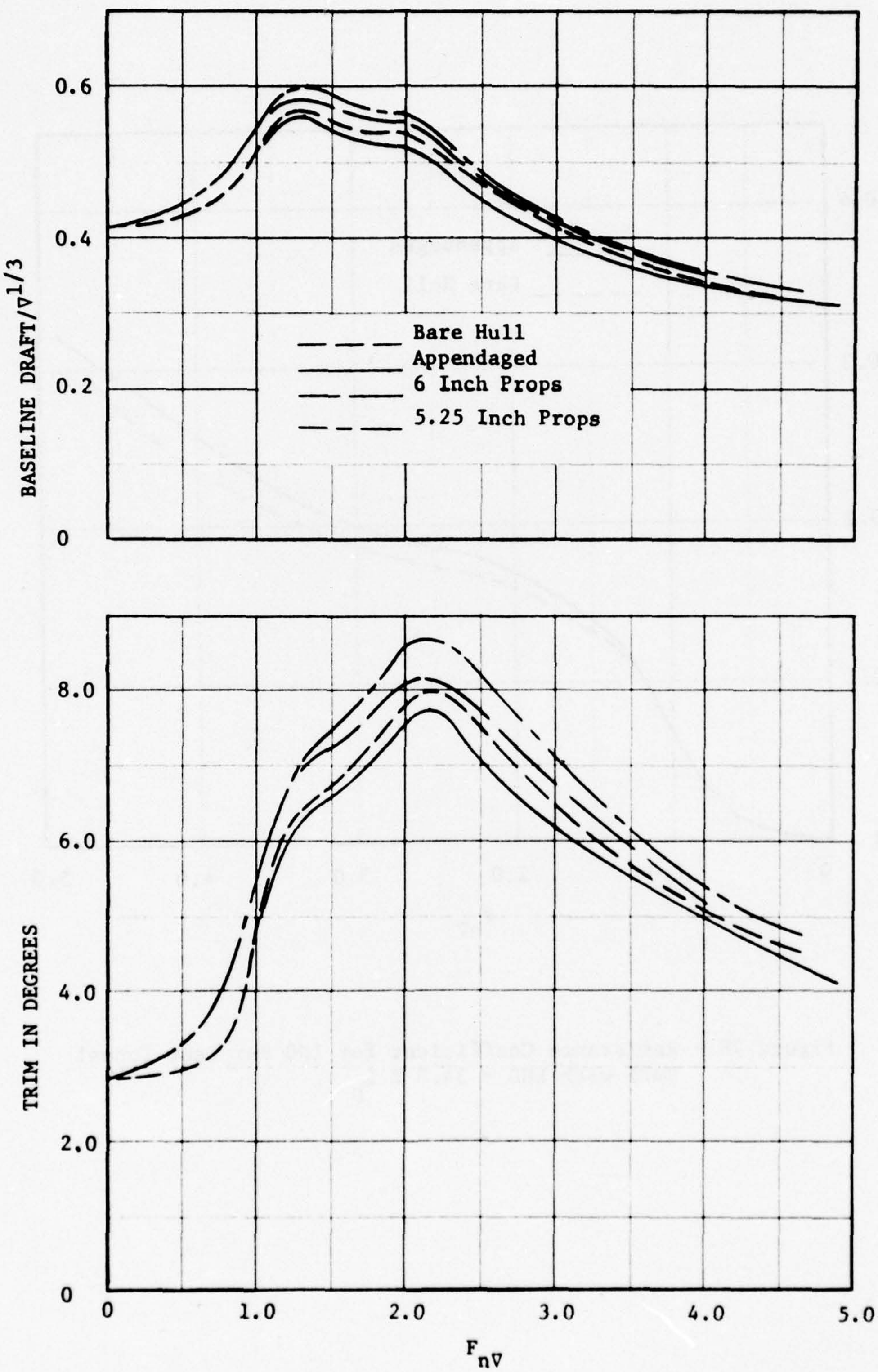


Figure 7A - Trim Angle and Baseline Draft of 100 Per Cent Tunnel Hull with LCG = 34.8% L_p

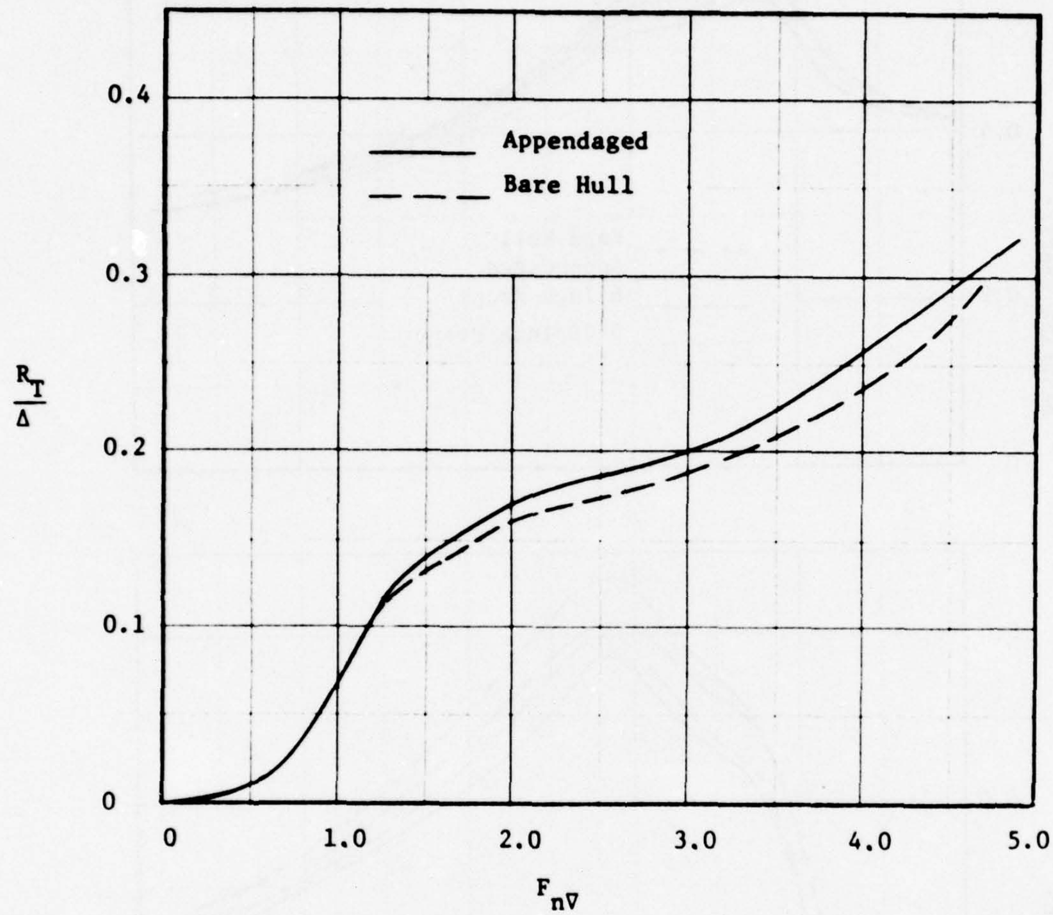


Figure 7B - Resistance Coefficient for 100 Per Cent Tunnel Hull with LCG = 34.8 % L_p

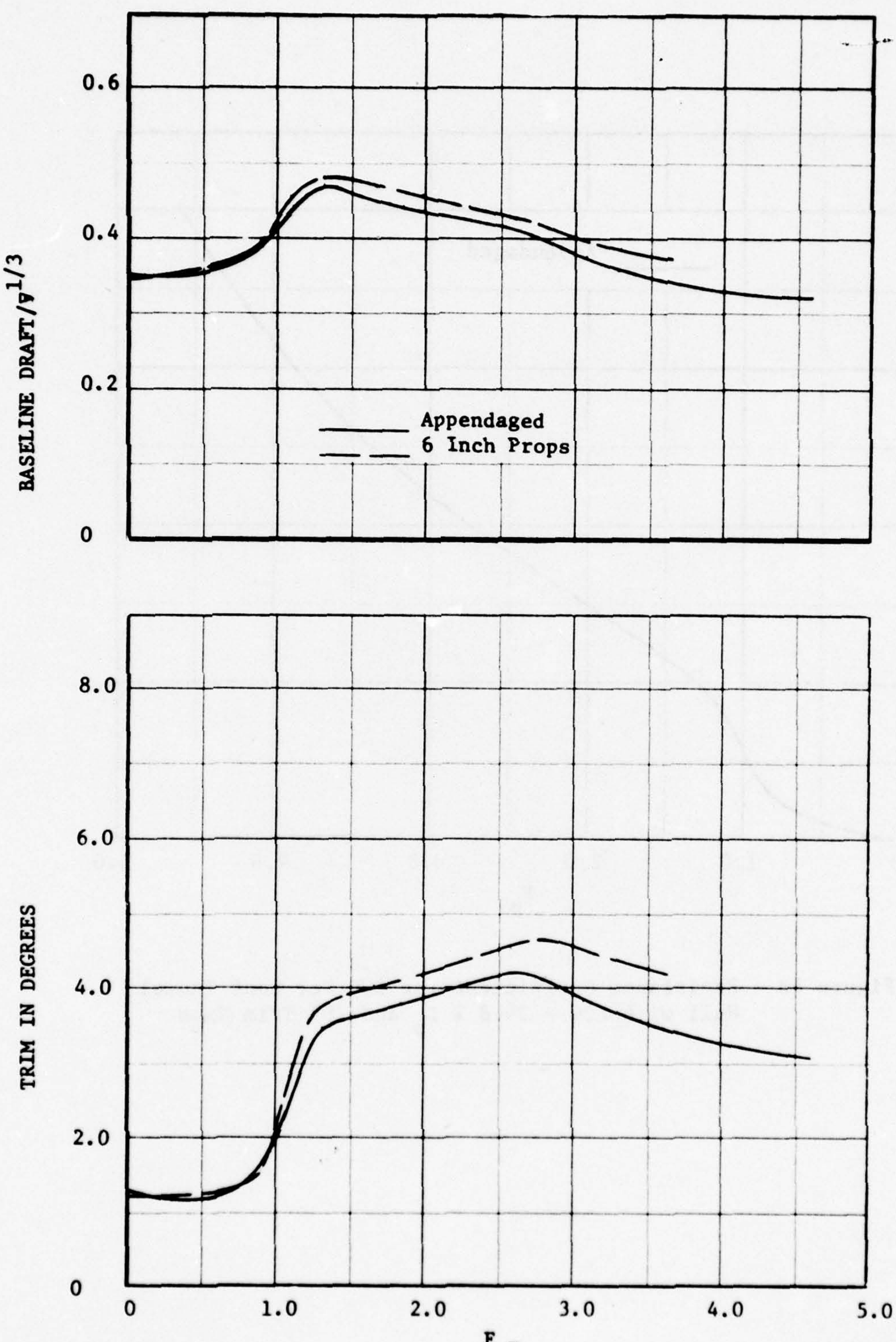


Figure 8A - Trim Angle and Baseline Draft of 100 Per Cent Tunnel Hull with LCG = 39.8 % L_p and 10° Trim Tabs

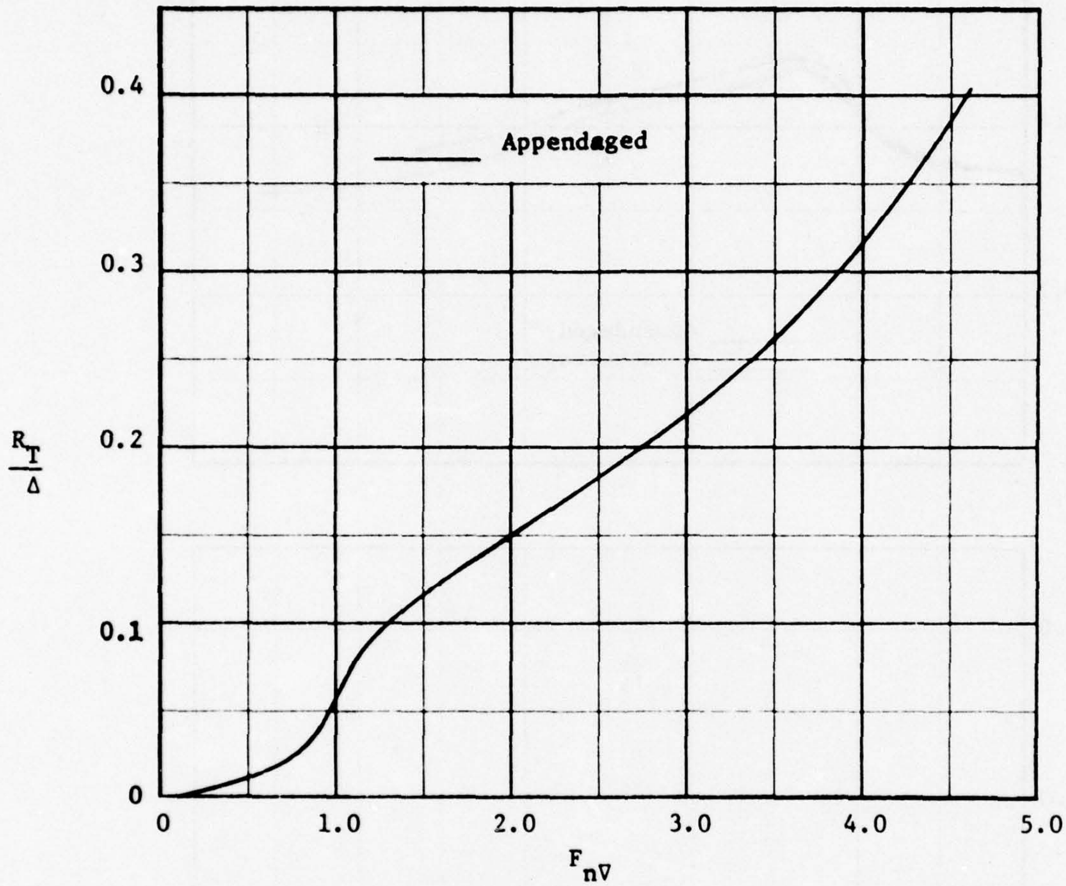


Figure 8B - Resistance Coefficient for 100 Per Cent Tunnel Hull with LCG = 39.8 % L_p and 10° Trim Tabs

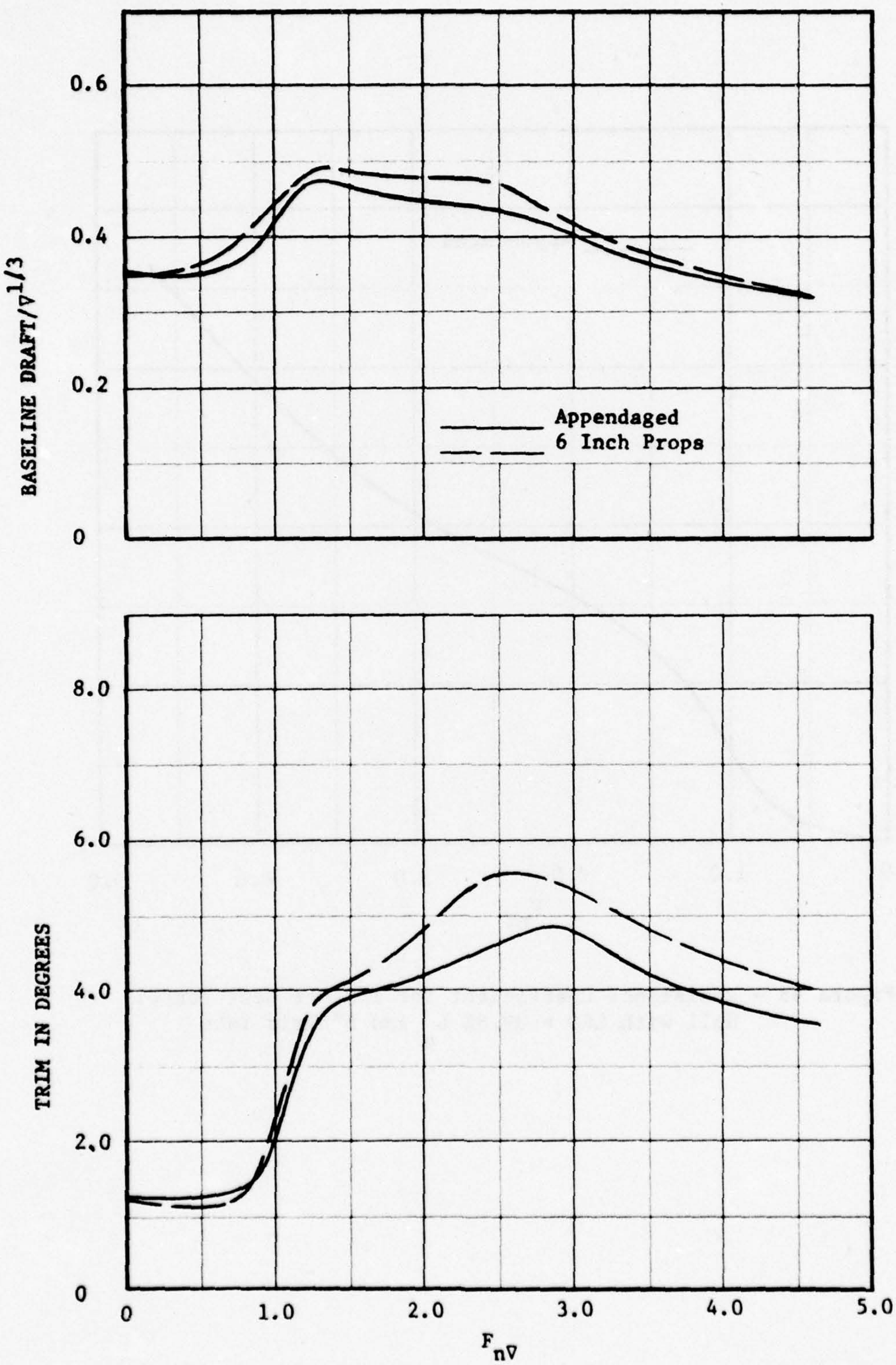


Figure 9A - Trim Angle and Baseline Draft of 100 Per Cent Tunnel Hull with LCG = 39.8% L_p and 5° Trim Tabs

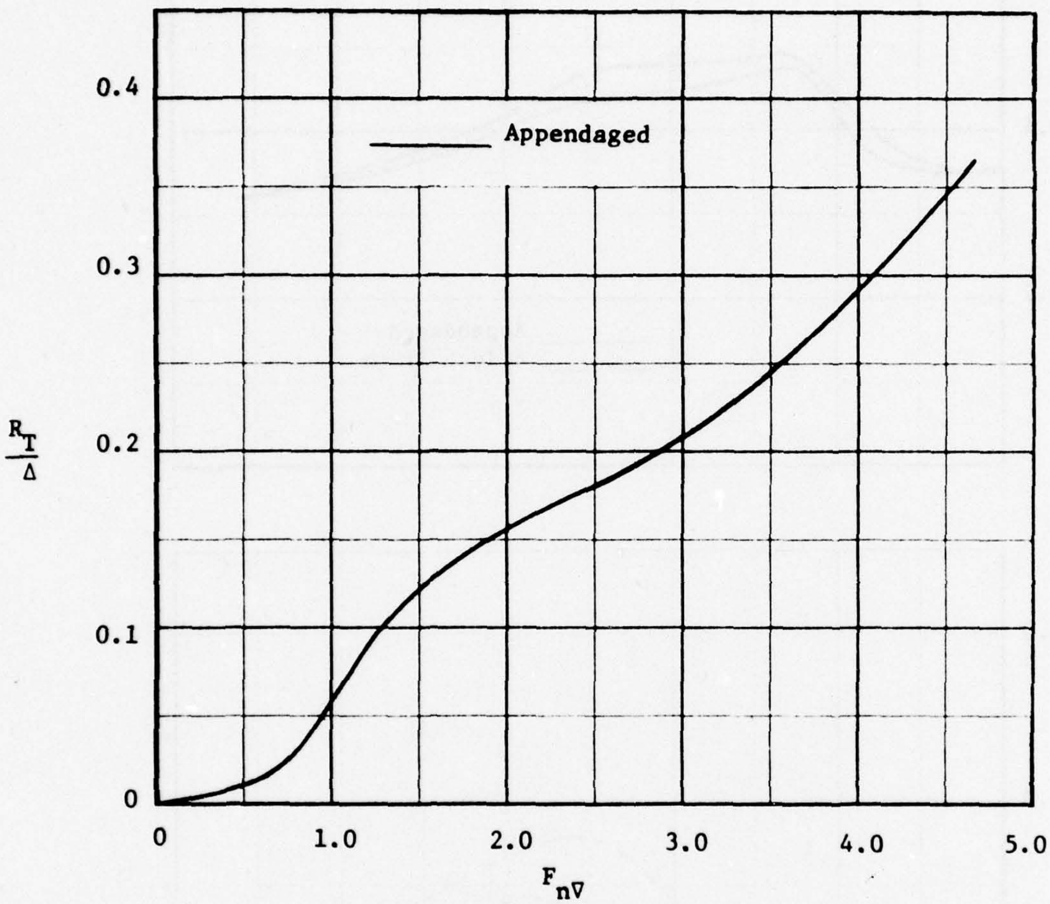


Figure 9B - Resistance Coefficient for 100 Per Cent Tunnel Hull with LCG = 39.8% L_p and 5° Trim Tabs

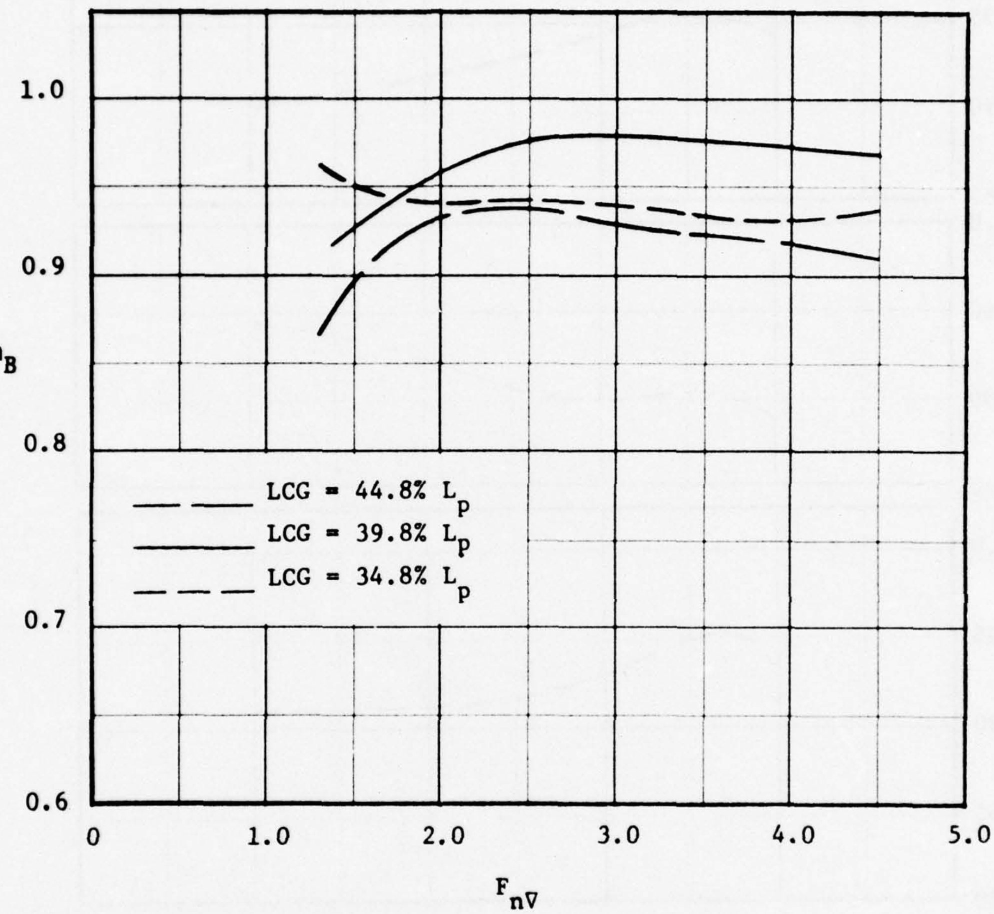


Figure 10 - Appendage Drag Factor η_B for 100 Per Cent Tunnel Hull

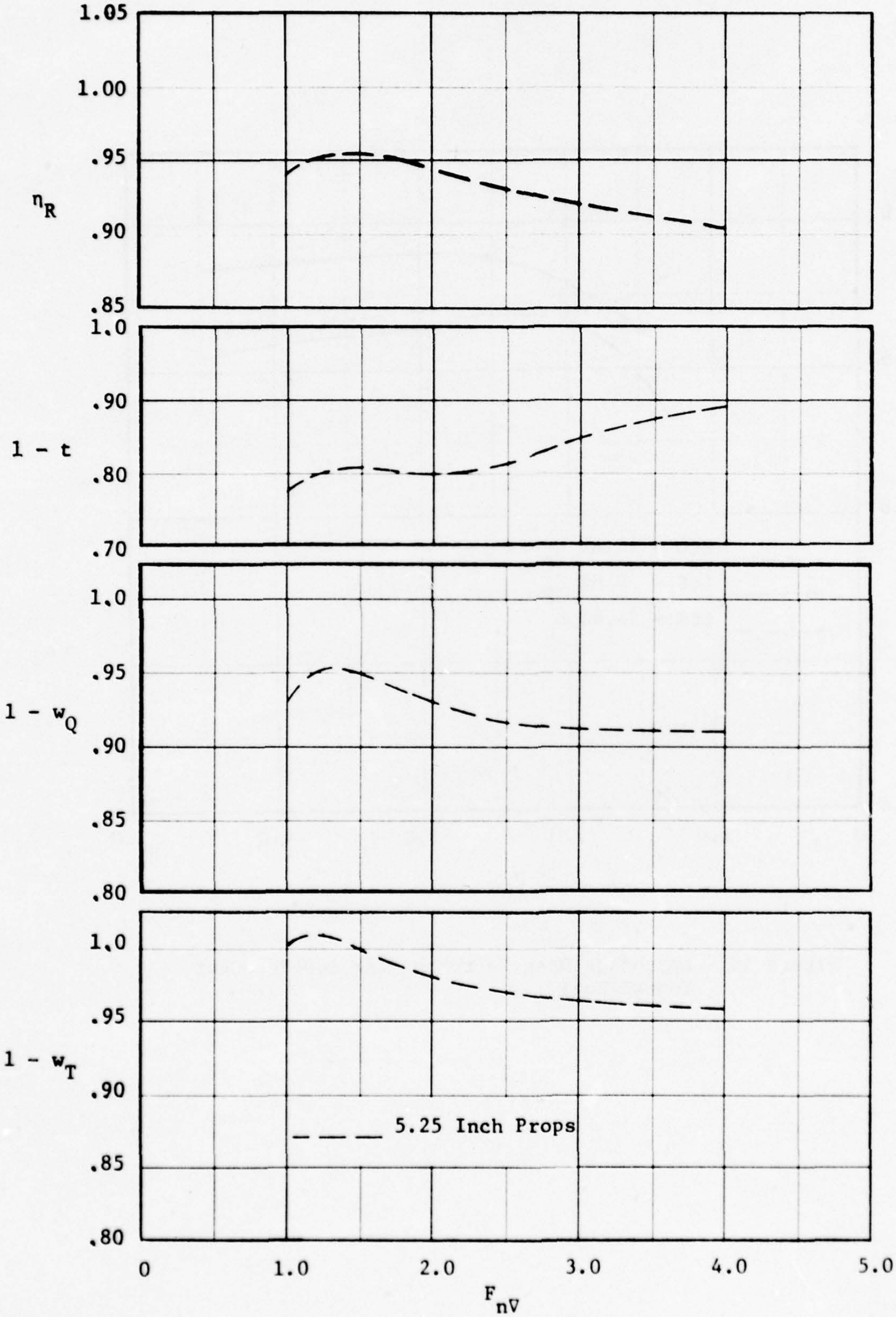


Figure 11 - Propulsive Characteristics: LCG = 39.8% L_p

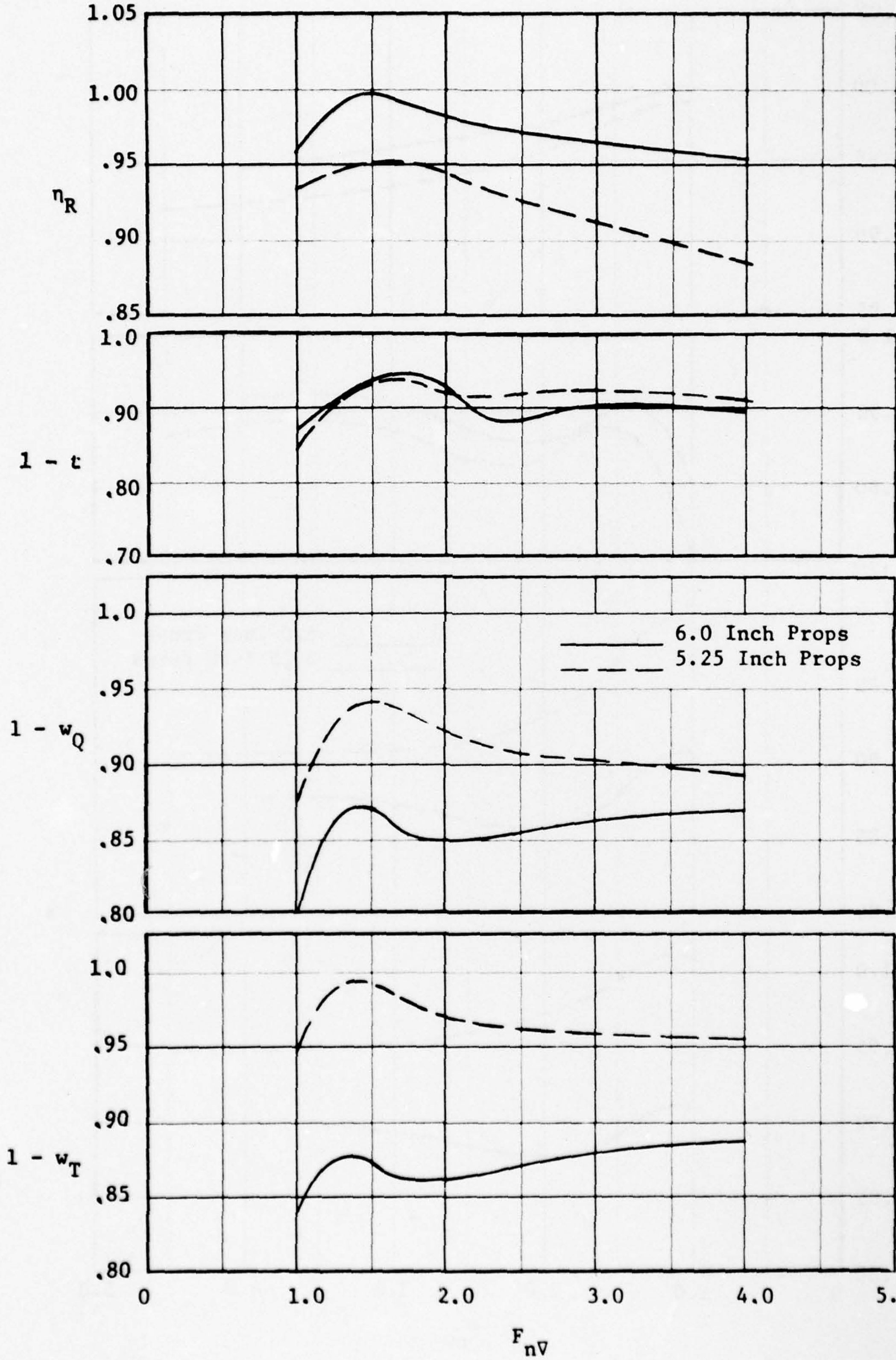


Figure 12 - Propulsive Characteristics: LCG = 44.8% L_p

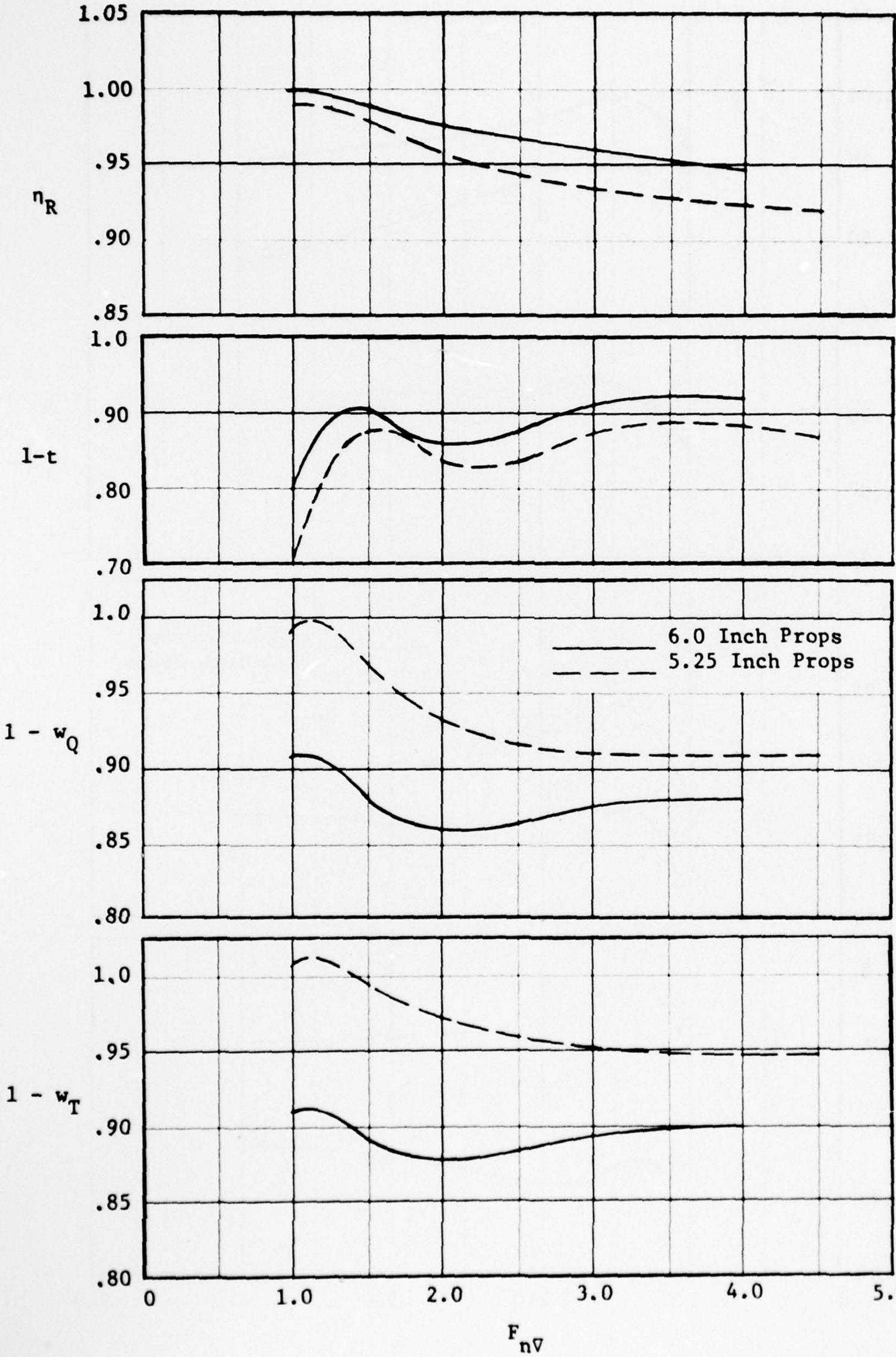


Figure 13 - Propulsive Characteristics: LCG = 34.8% L_p

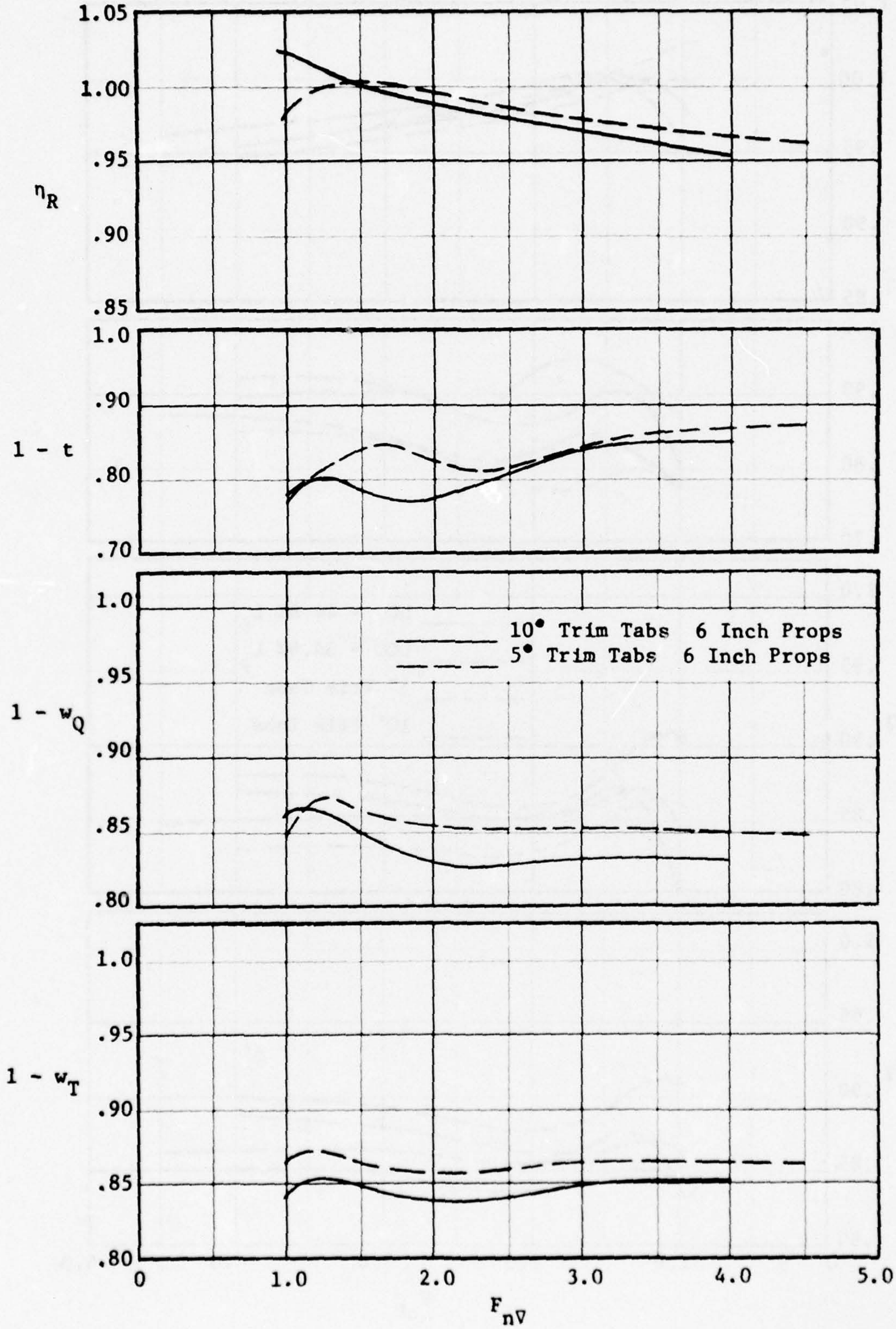


Figure 14 - Propulsive Characteristics: 5° and 10° Trim Tabs

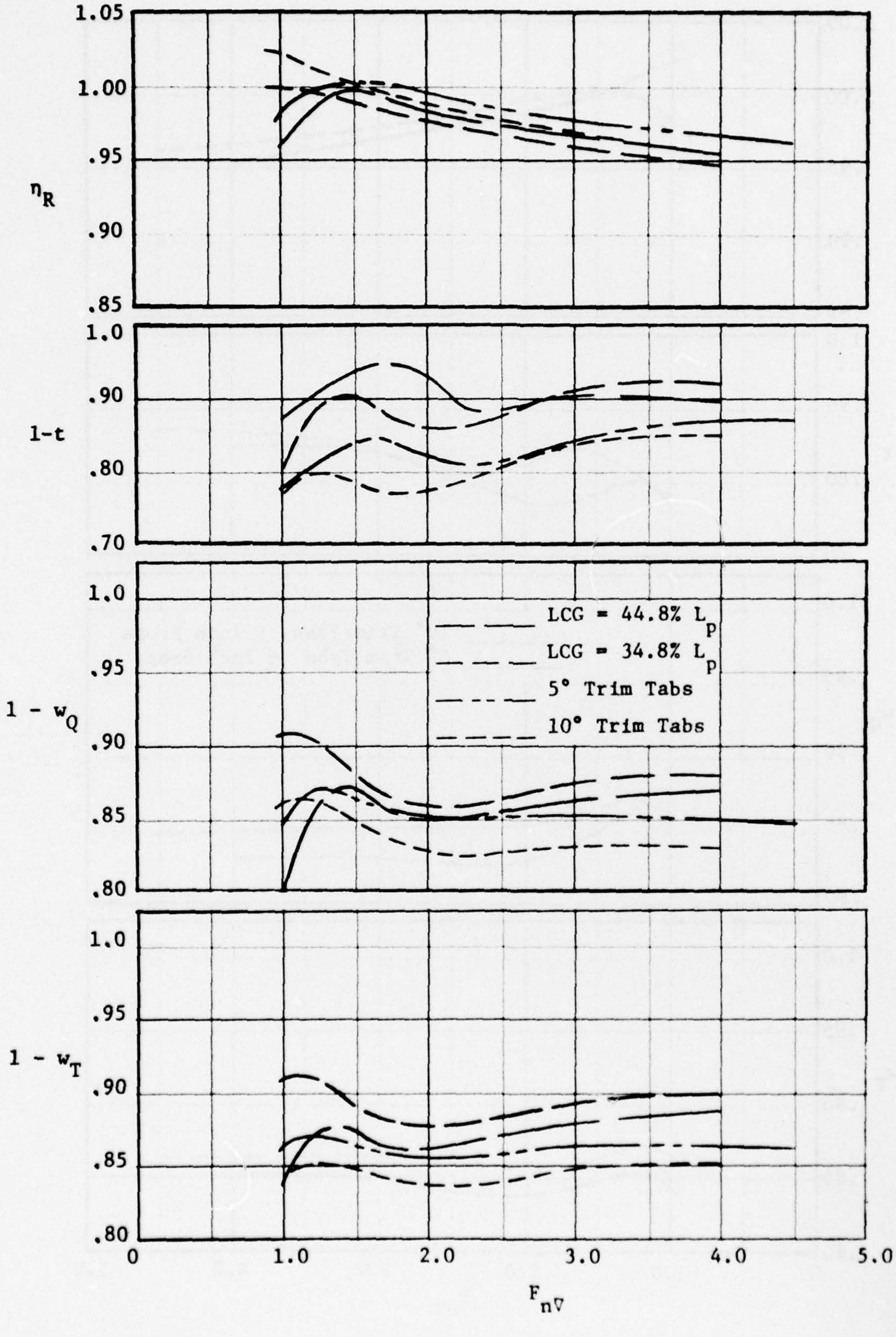


Figure 15 - Summary of Propulsive Characteristics for 100 Per Cent Tunnel Hull with 6 Inch Propellers

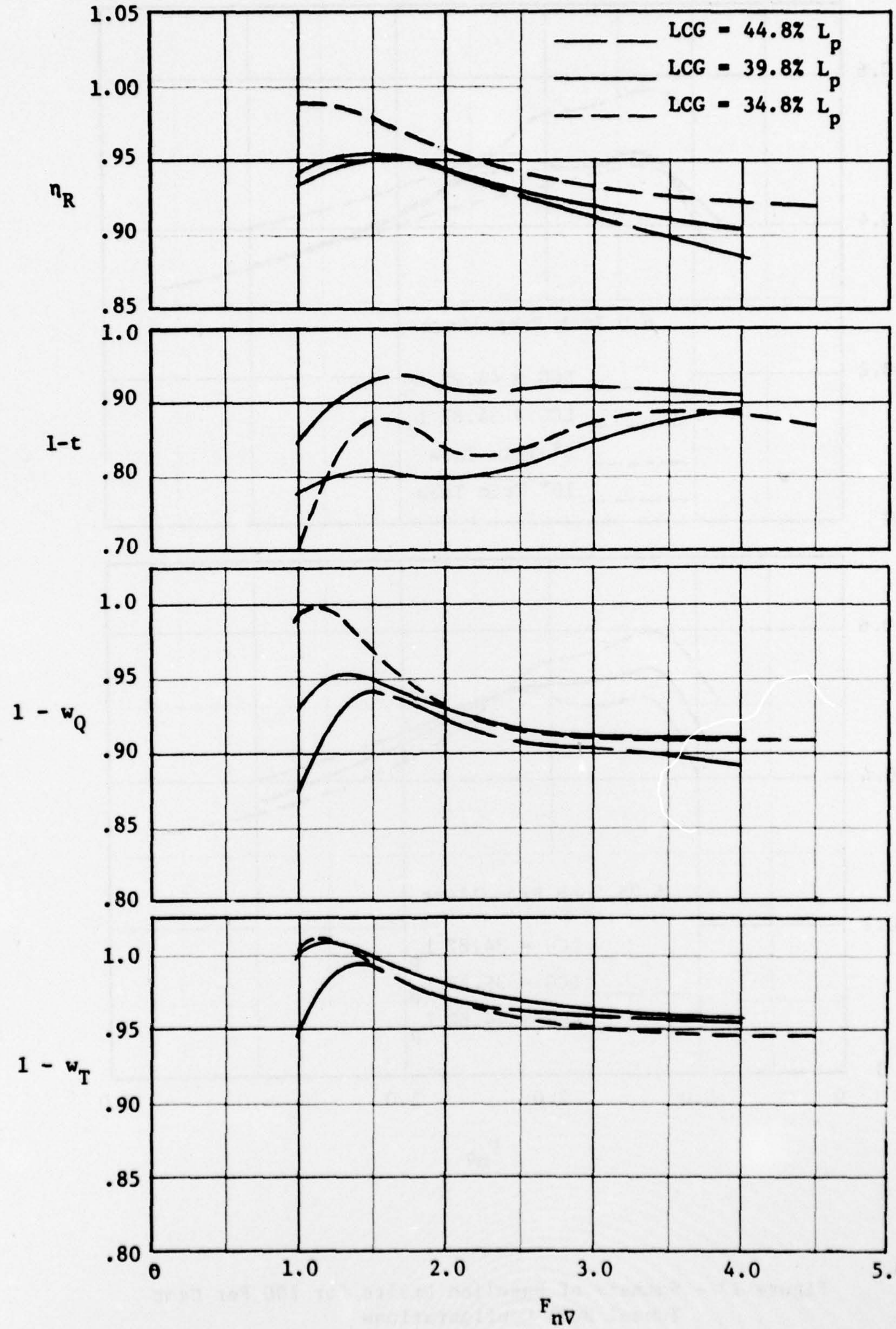


Figure 16 - Summary of Propulsive Characteristics for 100 Per Cent Tunnel Hull with 5.25 Inch Propellers

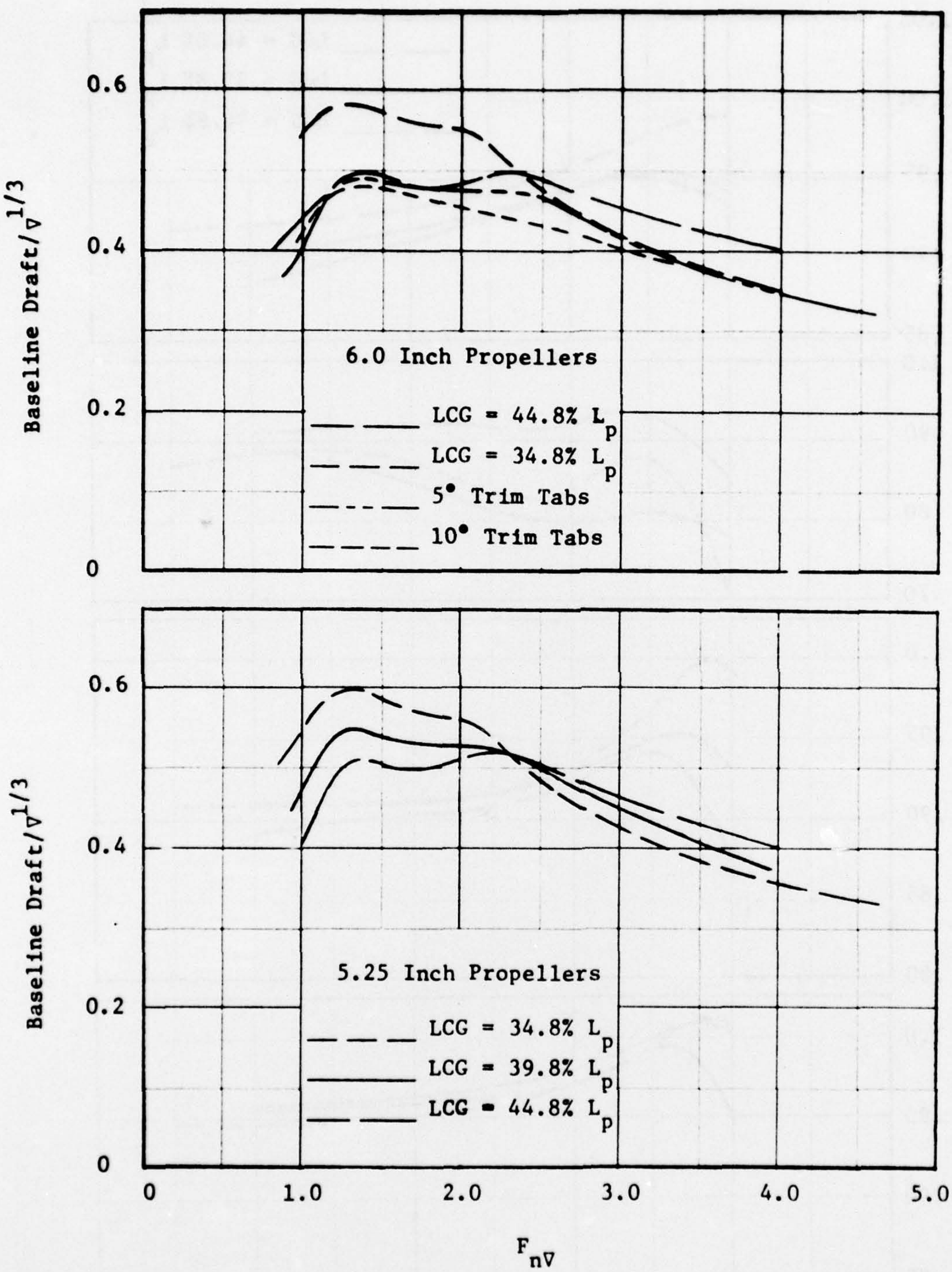


Figure 17 - Summary of Baseline Drafts for 100 Per Cent Tunnel Hull Configurations

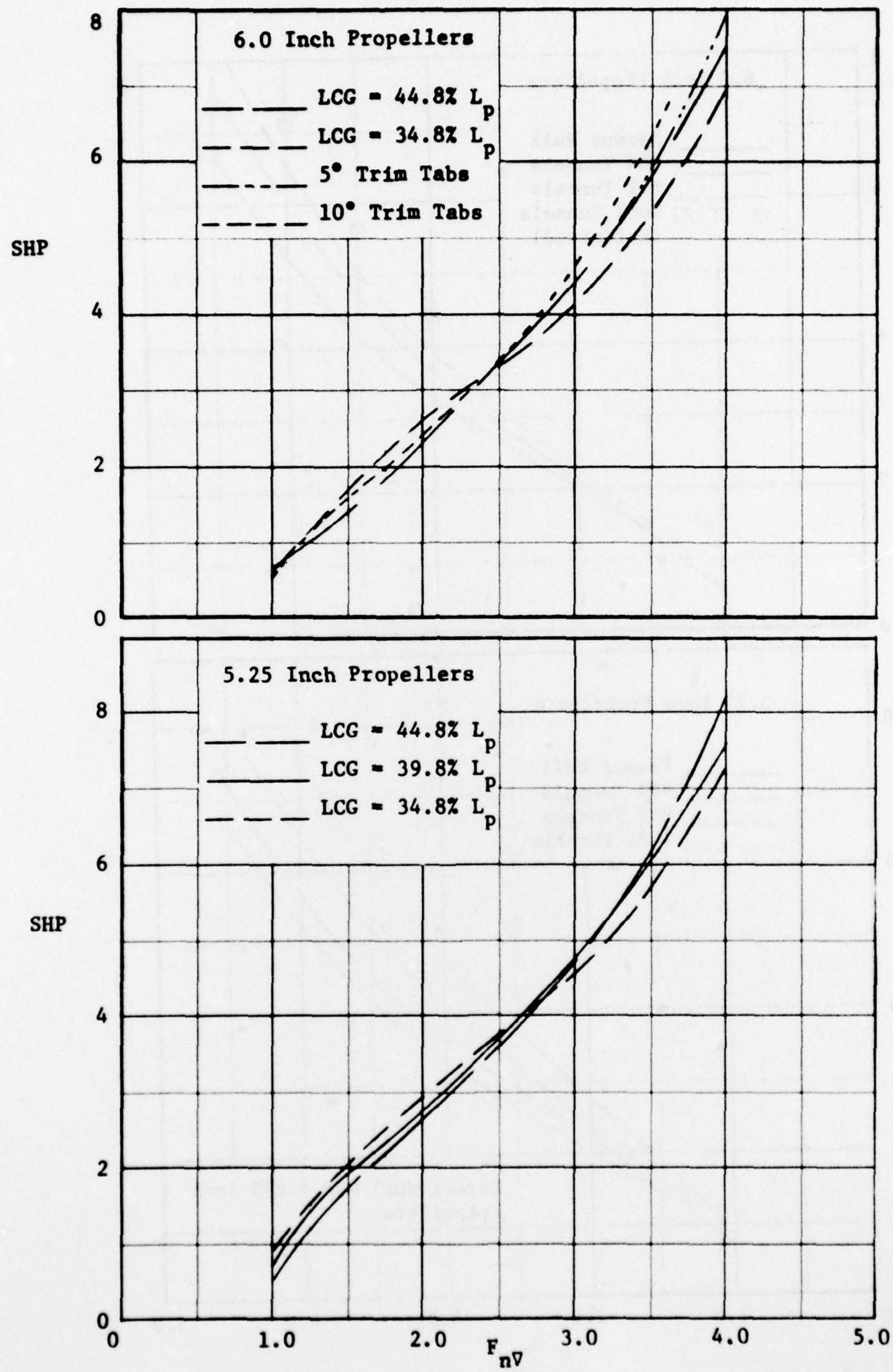


Figure 18 - Summary of Shaft Power Requirements for 100 Per Cent Tunnel Hull Configurations

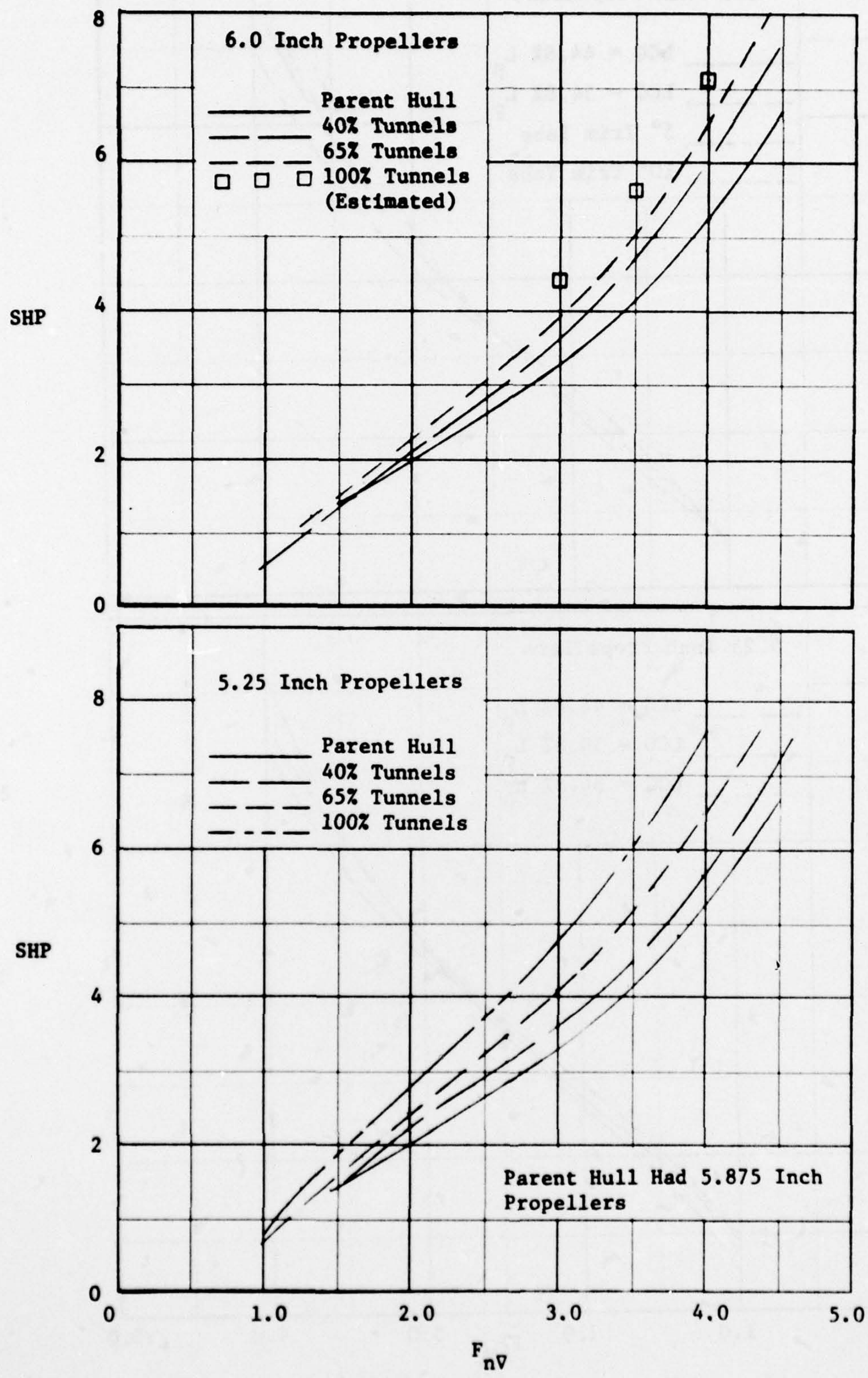


Figure 19 - Shaft Power Required For Parent and Tunnel Hull Craft

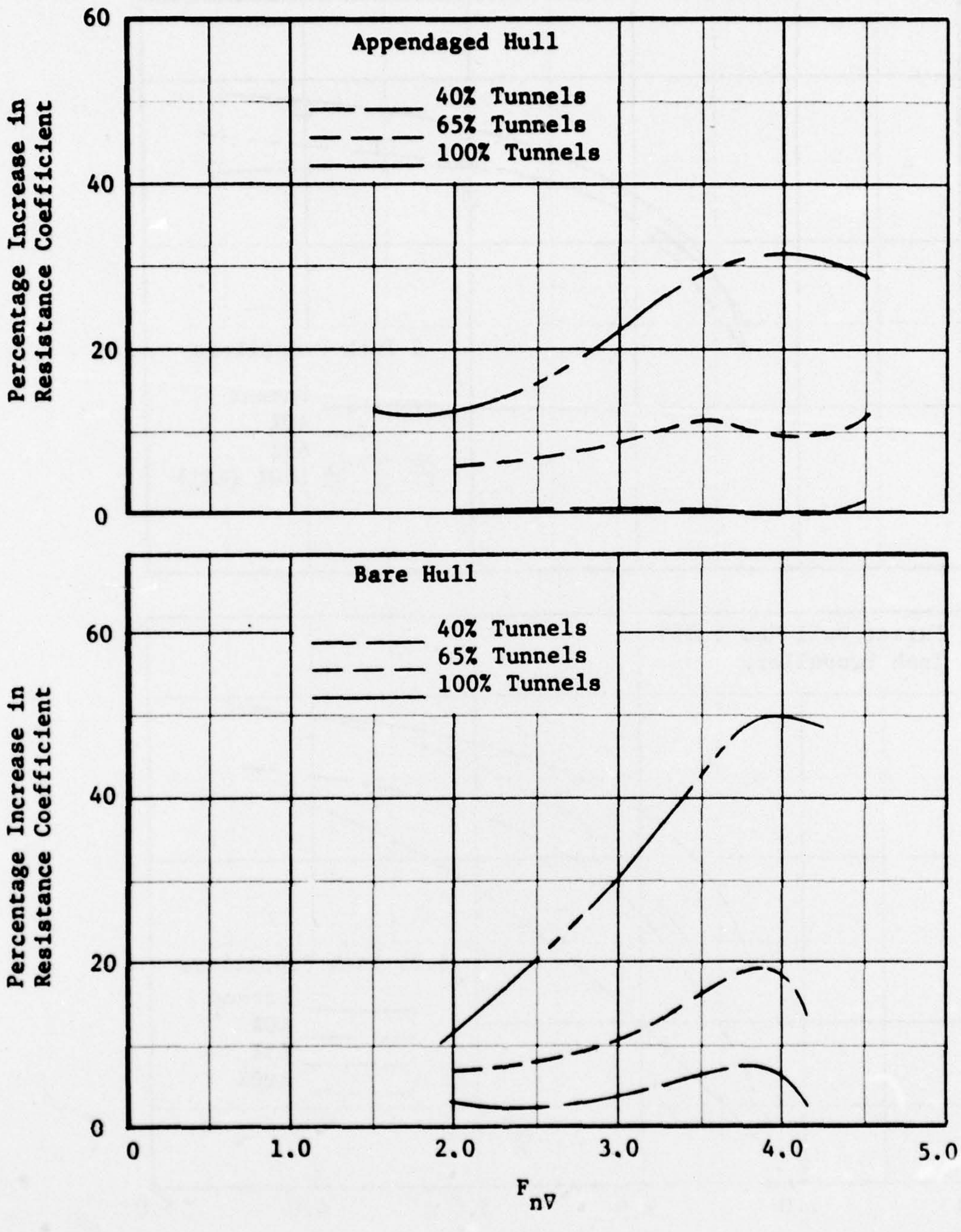
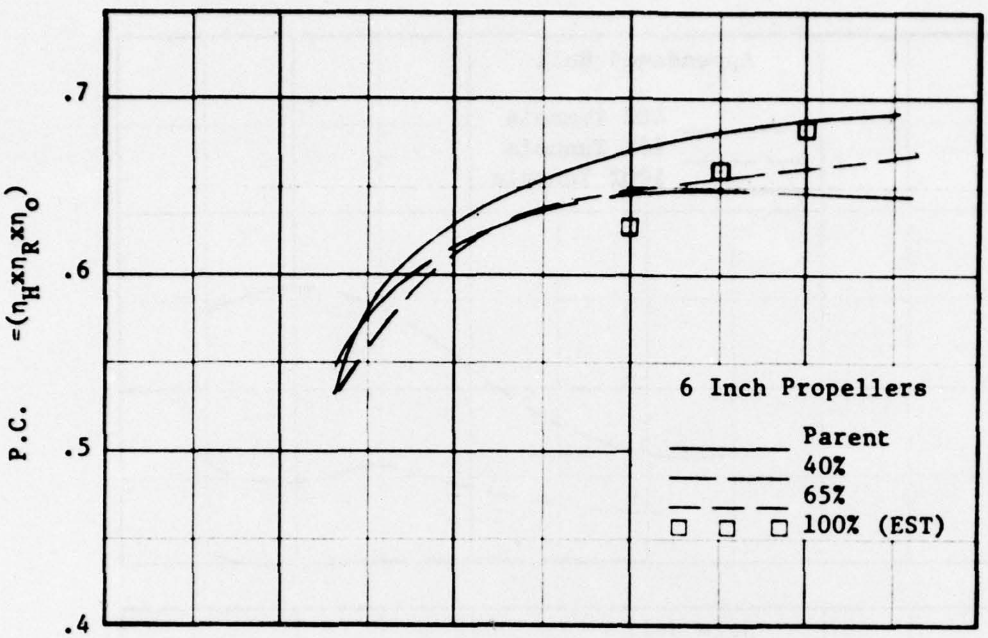


Figure 20 - Percentage Increase in Resistance Coefficient Over Parent Hull for Three Tunnel Depths



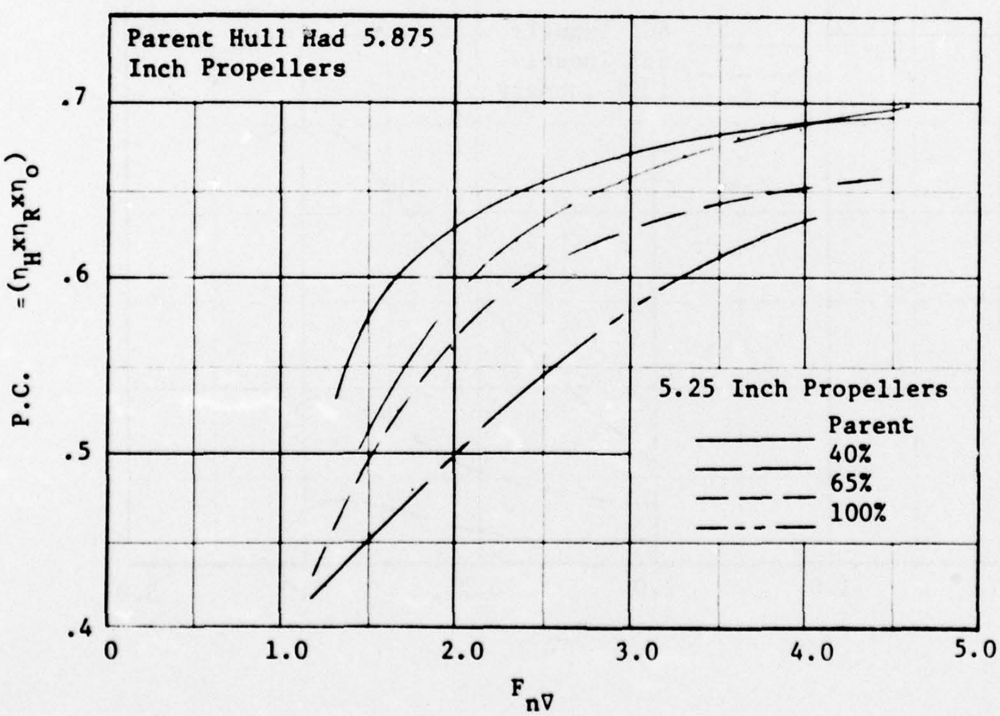


Figure 21 - Summary of Propulsive Coefficients for Parent and Tunnel Hulls

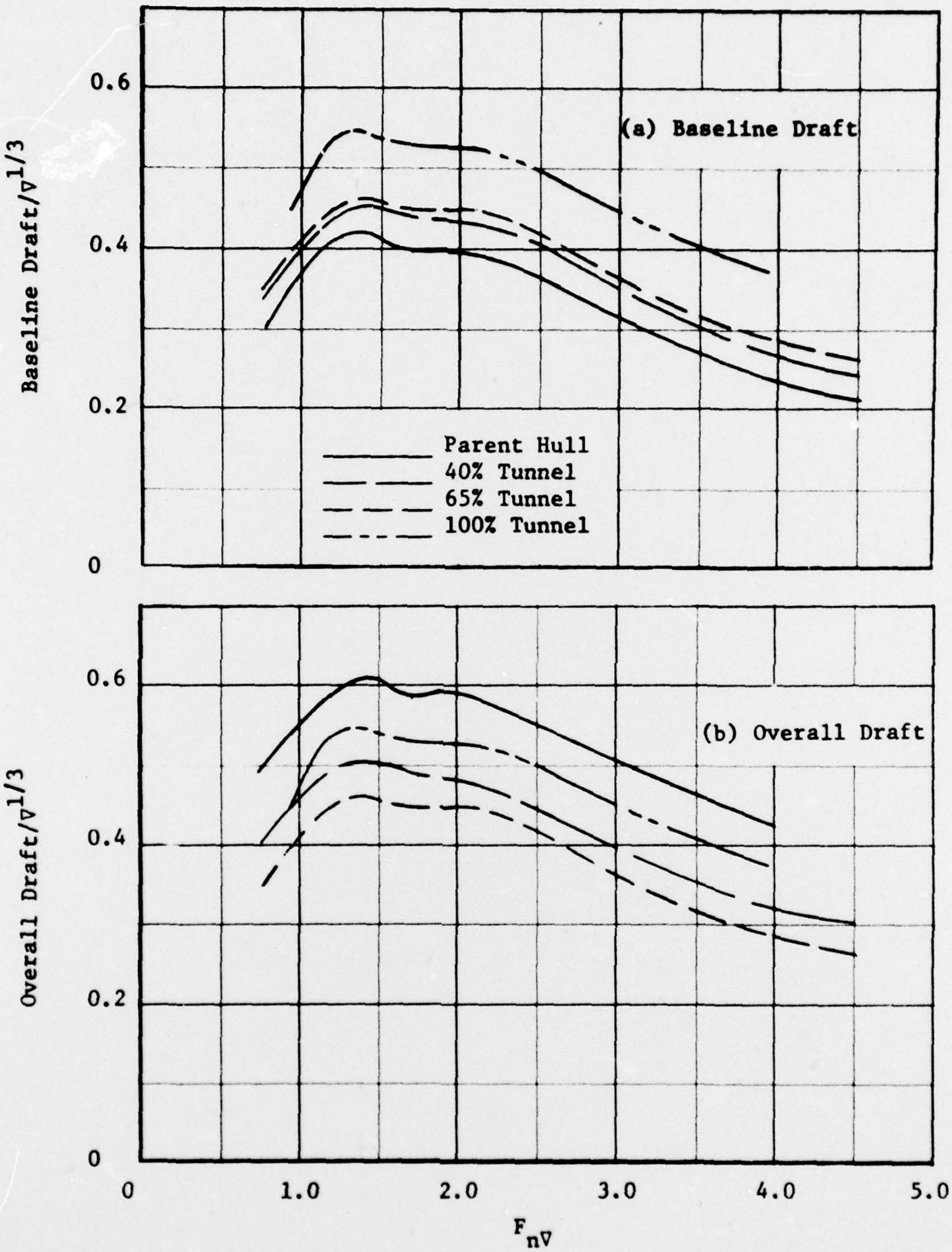


Figure 22 - Baseline Draft and Overall Draft for Parent and Tunnel Hull Craft

ADDENDUM

CORRECTIONS AND ADDITIONS TO "AN EXPERIMENTAL STUDY OF A HIGH-PERFORMANCE TUNNEL HULL CRAFT" BY K. HARBAUGH AND D.L. BLOUNT, SNAME, APRIL 1973.

Since the above paper was published, errors have been discovered in Figures 10 and 16 of that report. At the request of the authors, corrected versions of these figures are presented here. Additional data for the 100% tunnel hull are included for completeness.

The original Figure 10 was intended to illustrate the variation in η_A with F_{n_∇}. This factor allows for the conversion of bare parent hull resistance data to resistance of the appendaged tunnel hull. In fact, the curves given in the orginal Figure 10 represent η_B, the ratio of bare to appendaged hull resistance for the same hull form. The relationship can be expressed as

$$\eta_A = \frac{R_{T_{BP}}}{R_{T_{AX}}}$$

$$= \frac{R_{T_{BP}}}{R_{T_{BX}}} \times \frac{R_{T_{BX}}}{R_{T_{AX}}}$$

$$= \eta_C \times \eta_B$$

Obviously, then the curves are in error by a factor η_C, whose magnitude can be significant. Figure 7 of Reference 1 presents curves of $(\frac{1}{\eta_C} - 1) \times 100$ and $(\frac{1}{\eta_D} -1) \times 100$. These have been reworked and supplemented with 100% tunnel results and are given in Figure A1, as curves of η_C and η_D vs F_{n_∇}. This figure illustrates the magnitude of the error in the original curves of η_A. The error was carried through into the determination of the efficiency factor

$(\frac{1}{\eta_A \times \eta_H \times \eta_R})$ depicted as Figure 16 of Reference 1 and accounts for the more optimistic conclusions of Reference 1 compared to the current report as to the merits of the various tunnel hull forms.

Corrected Figures 10 and 16 for Reference 1 are appended as Figures A2 and A3, with additional data for the 100% tunnel hull. These figures can be used with the preliminary design method outlined in Reference 1 to obtain speed-power estimates based on parent hull speed-bare hull resistance relationships.

Notation

$R_{T_{AX}}$ Appended hull resistance: X=P for parent hull
X=T for tunnel hull

$R_{T_{BX}}$ Bare hull resistance: X=P for parent hull
X=T for tunnel hull

$$\eta_A = \frac{R_{T_{BP}}}{R_{T_{AX}}}$$

$$\eta_B = \frac{R_{T_{BX}}}{R_{T_{AX}}}$$

$$\eta_C = \frac{R_{T_{BP}}}{R_{T_{BX}}}$$

$$\eta_D = \frac{R_{T_{AP}}}{R_{T_{AX}}}$$

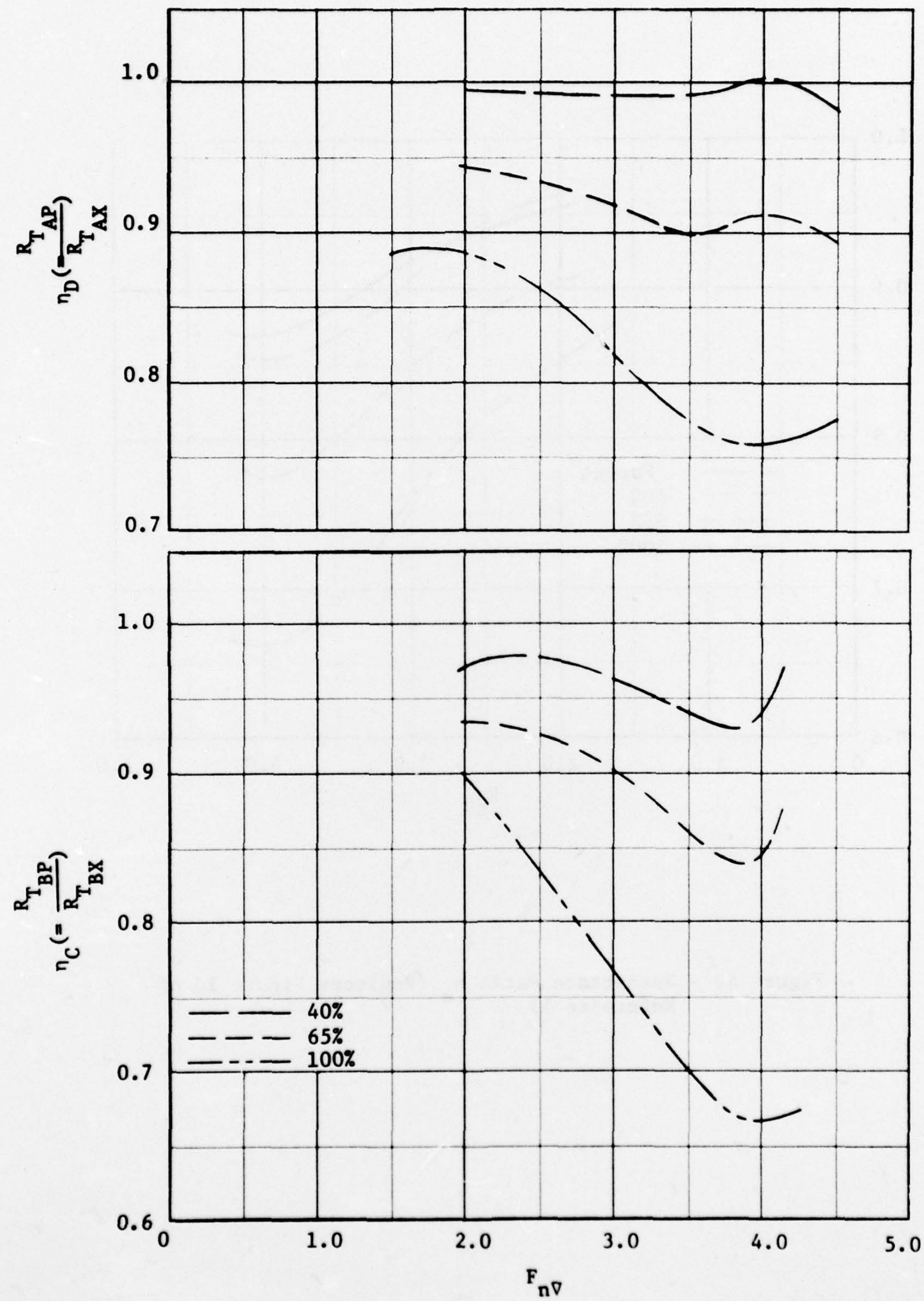


Figure A1 - Resistance Ratios η_C and η_D for Three Tunnel Hulls

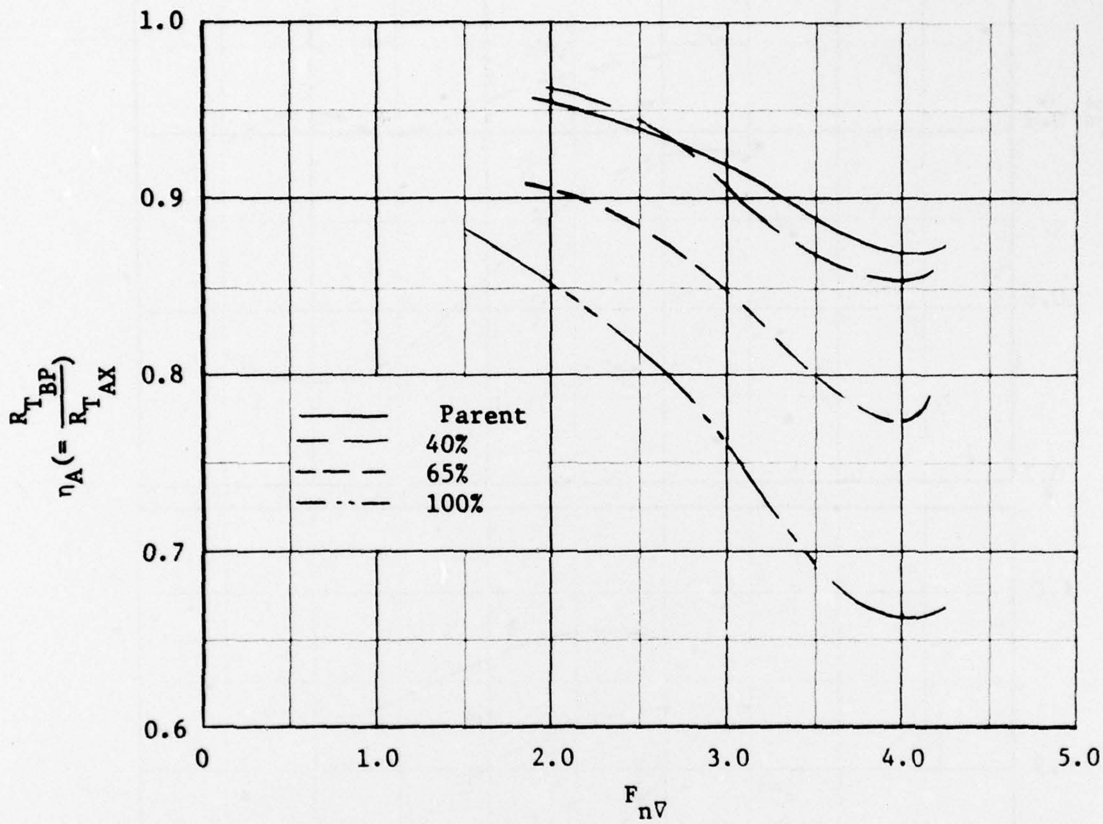


Figure A2 - Resistance Ratio η_A (Replaces Figure 10 of Reference 1)

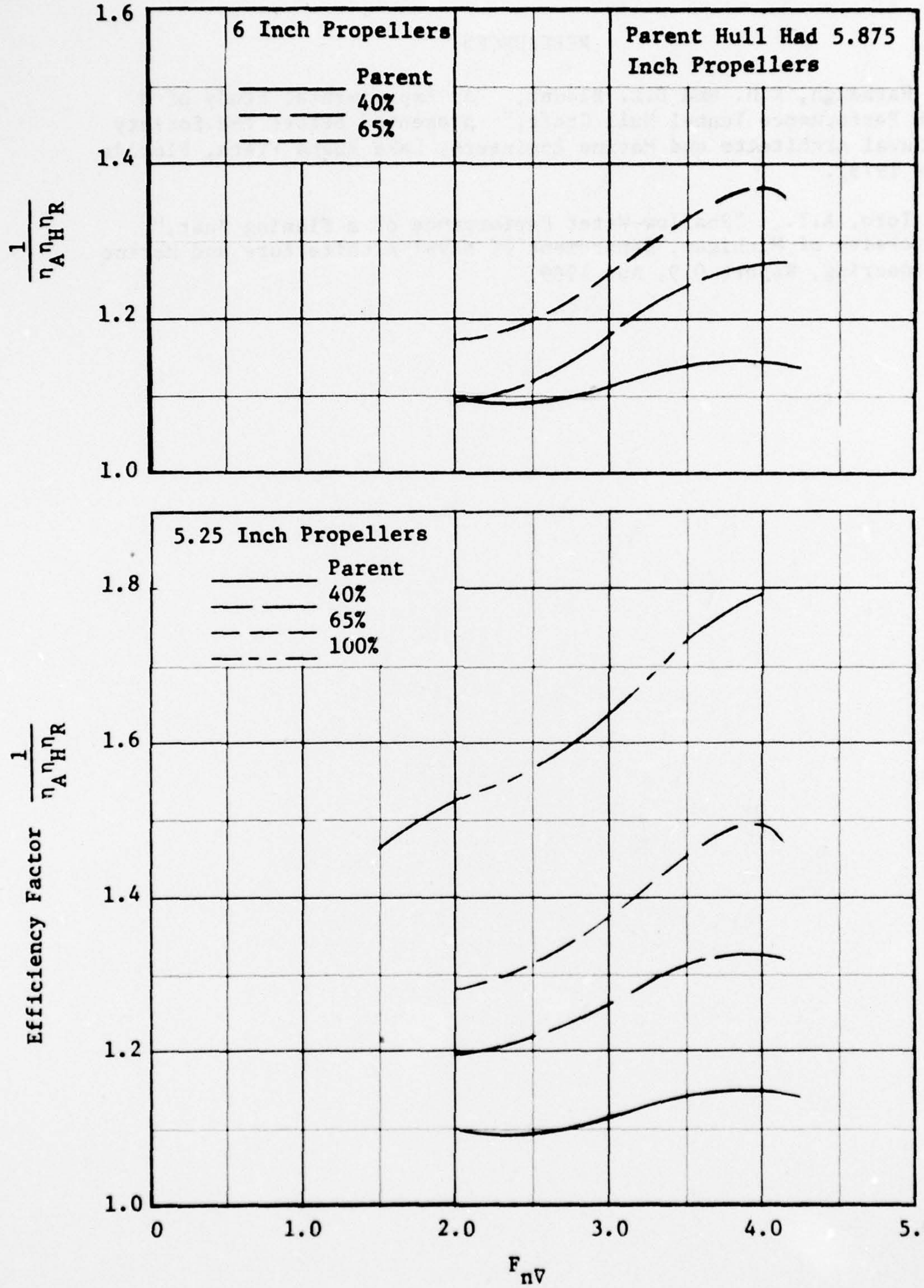


Figure A3 - Efficiency Factor $\frac{1}{\eta_A \eta_H \eta_R}$ (Replaces Figure 16 of Reference 1)

REFERENCES

1. Harbaugh, K.H. and D.L. Blount, "An Experimental Study of a High Performance Tunnel Hull Craft," presented before the Society of Naval Architects and Marine Engineers, Lake Buena Vista, Florida (Apr 1973).

2. Toro, A.I., "Shallow-Water Performance of a Planing Boat," University of Michigan, Department of Naval Architecture and Marine Engineering, Report 019, Apr 1969.

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